**TECHNICAL REPORT STANDARD PAGE**

| 1. Report No. **FHWA/LA.11/478** | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| 4. Title and Subtitle **Cost Effective Prevention of Reflective Cracking of Composite Pavement** | 5. Report Date September 2011<br>6. Performing Organization Code LTRC Project Number: 08-1P SIO Number: 30000144 | |
| 7. Author(s) **Mostafa Elseifi, Ph.D., and Rakesh Bandaru** | 8. Performing Organization Report No. | |
| 9. Performing Organization Name and Address Department of Civil and Environmental Engineering Louisiana State University Baton Rouge, LA 70803 | 10. Work Unit No.<br>11. Contract or Grant No. | |
| 12. Sponsoring Agency Name and Address Louisiana Department of Transportation and Development P.O. Box 94245 Baton Rouge, LA 70804-9245 | 13. Type of Report and Period Covered **Final Report 2008-2010**<br>14. Sponsoring Agency Code LTRC | |

15. Supplementary Notes
**Conducted in Cooperation with the U.S. Department of Transportation, Federal Highway Administration**

16. Abstract

Louisiana experimented with various techniques and treatments to control reflective cracking since the 1970s. The objective of this study is to evaluate and compare different reflective cracking control treatments by evaluating the performance, constructability, and cost-effectiveness of pavements built with these treatments across the state. To achieve this objective, a survey of current state practices identified the treatment methods that are used or that had been used to delay and mitigate reflective cracking in composite pavements. Based on this survey and a thorough review of LADOTD databases, pavement sections built with reflective crack control treatment methods were identified. Projects with sufficient years in service and with available untreated segments were selected for detailed performance and economic evaluation. In total, the performance of 50 different sites that were constructed with various treatments was evaluated for a period ranging from 4 to 18 years. Among various treatments that were analyzed, saw and seal, and chip seal as a crack relief interlayer showed the most promising results in terms of performance and economic worthiness. The cost effectiveness of fiber-glass grid was not validated as compared to regular HMA overlays. Stress absorbing membrane interlayer and high strain asphalt crack relief interlayer (STRATA®) showed mixed results in terms of performance. In addition, there were an insufficient number of projects for paving fabrics to allow for drawing conclusions on the cost-effectiveness of this treatment method.

| 17. Key Words Reflective cracking, rehabilitation, saw and seal | | 18. Distribution Statement **Unrestricted. This document is available through the National Technical Information Service, Springfield, VA 21161.** | |
|---|---|---|---|
| 19. Security Classif. (of this report) | 20. Security Classif. (of this page) | 21. No. of Pages 128 | 22. Price |

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# Cost Effective Prevention of Reflective Cracking in Composite Pavements

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LTRC Project No. 08-1P
State Project No. 736-99-1518

conducted for

Louisiana Department of Transportation and Development
Louisiana Transportation Research Center



September 2011

ABSTRACT

Louisiana has experimented with various techniques and treatments to control reflective cracking since the 1970s; however, the cost-effectiveness and performance of these methods were not evaluated in many projects. In addition, scientific evaluation and testing of the treatment methods were not performed on many projects. To ensure successful control of this distress and effective allocation of maintenance funds, there is a critical need to assess the performance of pavement sections across the state built with various treatment methods and to determine the most cost-effective techniques to delay or to prevent reflective cracking in composite pavements. The objective of this study was to evaluate and compare different reflective cracking control treatments by evaluating the performance, constructability, and cost-effectiveness of pavements built with these treatments across the state.

To achieve this objective, a survey of current state practices identified the treatment methods used to delay and mitigate reflective cracking in composite pavements. Based on this survey and a thorough review of Louisiana Department of Transportation and Development (LADOTD) databases, pavement sections built with crack control treatment methods were identified. Projects with sufficient years in service and with available untreated segments were selected for detailed performance and economic evaluation. In total, the performance of 50 different sites that were constructed with various treatments was evaluated for a period ranging from 4 to 18 years. Results of this analysis assessed the benefits of these crack control techniques in terms of performance, economic worthiness, constructability, and long-term benefits.

Among various treatments that were analyzed, saw and seal and chip seal as a crack relief interlayer showed the most promising results in terms of performance and economic worthiness. The cost effectiveness of fiber-glass grid was not validated as compared to regular Hot-Mix Asphalt (HMA) overlays. Stress absorbing membrane interlayers and high strain asphalt crack relief interlayers (STRATA®) showed mixed results in terms of performance. In addition, there was an insufficient number of projects for paving fabrics to allow for drawing conclusions on the cost-effectiveness of this treatment method.

# ACKNOWLEDGMENTS

The authors recognize the efforts of Said Ismail, Ashley Horne, and Christophe Fillastre of LADOTD, who cooperated with the research team during this project. This was critical for assessing and interpreting the Pavement Management System (PMS) data used in this study. The authors would also like to acknowledge the assistance of Mark Morvant, Kevin Gaspard, and Mitchell Terrell of the Louisiana Transportation Research Center (LTRC).

The U.S. Department of Transportation (USDOT), Federal Highway Administration (FHWA), and LADOTD through LTRC financially supported this research project.

# IMPLEMENTATION STATEMENT

Based on the findings and the results of this project, the field performance and cost-effectiveness of various treatment methods across the state were evaluated. The generated knowledge from this project will be of interest to the Department and to district engineers to assist them in the selection of crack control treatment methods that would be effective in delaying reflective cracking in composite pavements. Results should be implemented by the department through the development of a crack control policy that recommends specific rehabilitation strategies for composite pavements.

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# INTRODUCTION

Reflective cracking is caused by discontinuities (cracks or joints) in underlying layers, which propagate through an HMA overlay due to continuous movement at the crack prompted by thermal and traffic loading.  If the new overlay is bonded to the distressed layer, cracks in the existing pavement usually propagate to the surface within one to five years; as early as a few months have been reported *[1]*.  Excessive seasonal thermal variations and movements of a cement-treated base layer may also result in shrinkage cracking, which extends to the pavement surface to cause reflective block cracks.  Reflective cracking leads to premature failure of the overlay and allows water infiltration through the cracks, which causes stripping in HMA layers and weakening and deterioration in the base and/or subgrade.

Reflective cracking in HMA overlays represents a serious challenge associated with pavement rehabilitation.  Since the early 1930s, considerable resources and efforts have been spent to find new and relatively inexpensive techniques to delay reflective cracking *[2]*.  Different methods, including the use of interlayer systems, have been suggested for enhancing pavement resistance to reflective cracking.  Experimental investigations in the early 1980s showed that interlayer systems might be used to delay or to prevent the reflection of cracks through a new overlay placed over an old cracked pavement *[3]*.

Louisiana experimented with various techniques and treatments to control reflective cracking since the 1970s *[4]*; however, the performance and cost-effectiveness of these methods were not evaluated in many projects.  Performance and economical assessments of these various treatment methods present a critical need to ensure successful control of this distress and effective use of available funds.  Therefore, it is necessary to analyze various pavements across the state in which these treatments were used to establish the performance and cost effectiveness of these crack control methods.

## Literature Review

HMA overlays are applied to an existing pavement (flexible or rigid) when the structural or functional conditions of the pavement have reached an unacceptable level of deterioration.  Most of the overlays are designed to reflect an increase in pavement resistance to fatigue and rutting distresses *[5], [6]*.  However, pavements that are structurally sound after the placement of the overlay, and that are adequately designed against rutting and fatigue distresses, may show cracking patterns similar to existing ones in the old pavement after a short period of time *[7]*.  This pattern is known as "reflective cracking."  Although certainly the most common failure mechanisms in rehabilitated pavements, the reflection of existing discontinuities in the pavement through the overlay, is rarely considered in the design process.

Field experiences indicate that reflective cracks usually propagate to the pavement surface at a rate of approximately 1 inch per year and appear at the surface, in most cases, within three years or less *[8]*.  Common problems associated with reflective cracking include discomfort to the users, reduction of user safety, intrusion of water thereby reducing the bearing capacity of the underlying layers, pumping of soil particles, and progressive degradation of road structure.  The process of the reflective cracking failure mechanism is shown in Figure 1.

**Mechanism of Reflective Cracking**

According to Lytton, the passing of a wheel load over a crack in the existing pavement causes three critical pulses (one maximum bending and two maximum shear stresses). Although the level of agreement is highly influenced by the mix nominal aggregate size, the crack growth process in HMA might be accurately described using the fracture mechanics theory *[9]*.

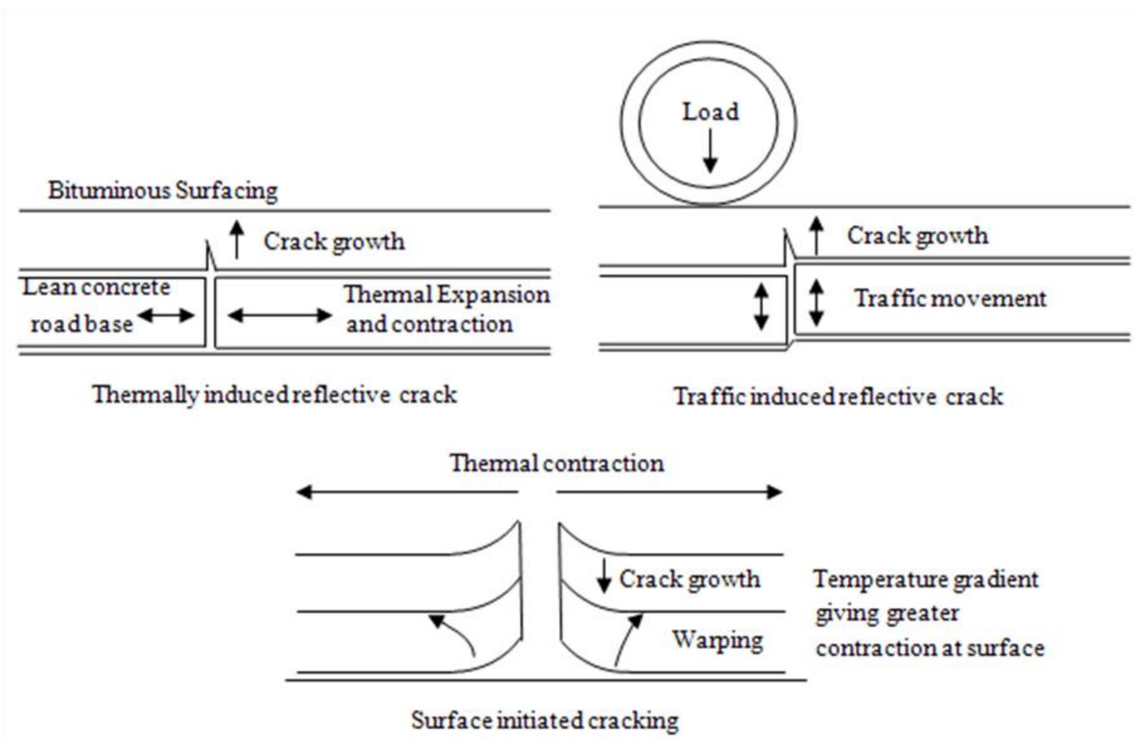



**Figure 1**
**Mechanisms of reflective cracking *[10]***

Generally, loads can be applied on a pavement structure in a combination of three fracture modes, which represent the worst cases of loading *[11]*:

- **Mode 1** loading results from loads that are applied normally to the crack plane (thermal and traffic loading).
- **Mode 2** loading results from in-plane shear loading, which leads to crack faces sliding against each other normally to the leading edge of the crack (traffic loading).
- **Mode 3** loading (tearing mode) results from out-of-plane shear loading parallel to the crack leading edge. This mode of loading is negligible for pavements.

### Propagation of Reflective Cracks

Propagation of reflective cracks in pavements is described in two distinct phases. Phase I is known as the crack initiation phase and Phase II is known as the crack propagation phase.

**Crack Initiation Phase.** This phase is explained in two distinct sub-phases of micro-cracking and the formation of macro-cracks and is defined by the necessary number of load applications to form a visible damaged zone at the bottom of the overlays. The original damage may occur at the bottom of the HMA layer and grow upwards, or it may show directly at the surface due to stress concentration around the tire treads. When reflection of crack is considered, the pavement service life against crack initiation may be much shorter than that resulting from regular distress as the crack is already well established in the existing pavement *[11]*.

**Crack Propagation Phase.** This stage describes the mechanism of crack propagation to the surface through the entire thickness of the HMA overlay. A description of the crack propagation phase in composite pavements can be based on the empirical power law developed by Paris and Erdogan as follows *[12]*:

$$\frac{dc}{dN} = A(\Delta K)^n \tag{1}$$

where,

c = Crack length;

n = number of loading cycles;

A and N = fracture parameters of material; and

$\Delta$K = Stress intensity factor amplitude.

## Types of Reflective Cracking

**Thermally-Induced Reflective Cracking.** Horizontal and vertical movements of underlying Portland cement concrete (PCC) pavement joints can cause reflective cracking. These movements are created by temperature variations. Hot mix asphalt can relax under slow moving conditions; therefore, daily temperature changes have a far more instrumental role to play in the performance of HMA than seasonal temperature changes. Tensile stresses are induced in the overlay right above the joint when contraction occurs during night time or during a cooling cycle. The most critical condition for development of reflective cracking with respect to horizontal slab movements occurs when the temperature drops from day time to night time. This critical temperature difference also develops shear and tensile stresses at the bottom surface of the overlay *[13]*.

The movement of reflective cracking due to thermal forces (daily and seasonal) is very important to understand, i.e., whether they initiate at the surface of a pavement (overlay) and grow downwards or they originate and propagate from an old crack or joint in the existing pavement structure upwards. The answer to this question is very important because the optimum or cost-effective maintenance strategy depends upon this factor. The effect of daily temperature cycles on the pavement can reach a depth of 2.3 feet *[14]*. The climatic conditions and physical properties of pavement materials like thermal diffusivity and depth below pavement surface are the main factors controlling the amplitude of temperature drop that pavement layers are subjected to. Low severity reflective cracks are those that initiate at the bottom of the overlay and eventually propagate to the surface with time. These cracks become more severe and eventually cause spalling when heavy thermal variations and traffic loads act upon them. Spalling allows for water infiltration to the underlying layers, which reduces the load bearing capacity of subgrade soils *[15]*.

The induction of tension into the overlay is dependent on the level from which the temperature drops. This drop occurs in two different ways. First, restrained shrinkage of the overlay itself causes transverse and longitudinal tensile stresses equal to $E \times \alpha \times \Delta T/(1-\upsilon)$ where **E** represents the stiffness of the overlay material, $\boldsymbol{\alpha}$ represents the thermal coefficient of contraction of mixture, and $\boldsymbol{\upsilon}$ represents Poisson's ratio; this is if the pavement has infinite dimensions *[14]*. Due to rate-dependent behavior of HMA and large temperature drops, stresses are at their maximum at the pavement surface. Aging of asphalt occurs because the surface of the pavement is exposed to traffic, environment, and other climatic factors. This mechanism results in initiation of a crack on the surface and propagates from the pavement surface downwards. This theory is not only applicable to older pavement surfaces but it can also occur in many new pavement structures. As these cracks are not due to differential displacements, reinforcement cannot prevent initiation of this type of crack. Usage of softer asphalt like styrene butadiene styrene (SBS)-polymer modified bitumen (asphalt) is recommended and the use of reinforcement is discouraged because it proved to be of no use *[14]*.

**Traffic-Induced Reflective Cracking.** Apart from weather conditions, traffic loading is an active mechanism for pavements to develop reflective cracking. Figure 2 represents the cracking pattern when the pavement is subjected to thermal and traffic loads. Many researchers believe that traffic loadings are not significant in initiating reflective cracking, but they worsen the pavement by accelerating the cracks that are initiated by thermal stresses *[14]*. The opening and shearing actions at the tip of a crack in an overlay placed on a cracked pavement are caused by traffic loadings. A traffic load also creates vertical movements in PCC slabs due to poor load transfer efficiency at the joints. These movements create bending and/or shear stresses underneath the asphalt overlay at the location of the joints, which in the course of time reflects to the surface *[13]*. The rate of crack propagation through a thin overlay of 2 in. was found to be negligible due to the passing wheel loads *[13]*. This happens because, for a small or consistent length of crack in the overlay, the stress intensity factor due to bending is found to be maximum and at the same time the stress intensity factor due to shearing is at its minimum. On the other hand, when the crack starts propagating to the top part of the overlay, the magnitudes of the stress intensity factors seem to alter exactly in an opposite way. The two factors governing the effectiveness of reinforcement keeping the pavement characteristics constant are stiffness and the restraint to pull out *[14]*. Subgrade modulus also has a significant role in influencing the magnitudes of shear and bending stresses caused by traffic loads. The values of bending and shear stress are inversely proportional to the modulus of subgrade *[13]*.

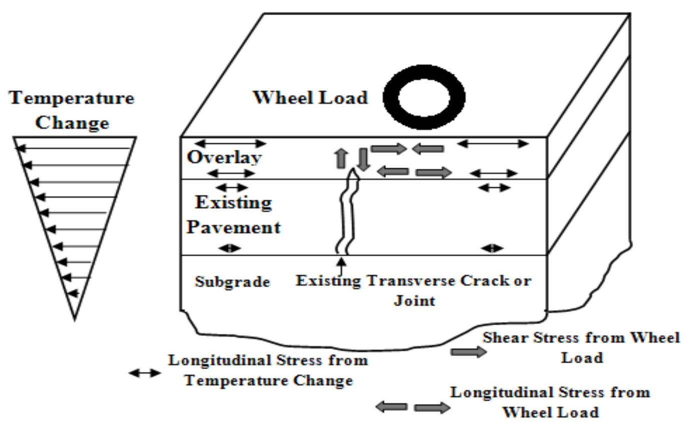



**Figure 2**
**Mechanism of origin of reflective cracks *[16]***

### Reflective Cracking in Semi-Rigid Pavements

A semi-rigid pavement structure consists of HMA overlays on top of a cement-treated aggregate base, which is placed on a subgrade. Newly constructed semi-rigid pavements experience reflective cracking as one of the major early distresses *[17]*. The state of stress at the bottom of the subgrade is found to be in compression when there are no cracks in the cement-treated aggregate base; shrinkage creates initial cracking in the base course, which shifts the compression state to high tensile stresses and strains in the vicinity of cracks. These cracks under repetitive traffic loads will lead to fatigue cracking at the bottom, which will eventually propagate to the surface as reflective cracks *[17]*. Ni et al. performed different laboratory tests on various samples to simulate field reflective cracking pattern. Test results indicate that the usage of high elasticity grade binder with low nominal maximum aggregate size (NMAS) could significantly delay the reflective crack propagation rate *[17]*.

A study performed by Gaspard et al. on shrinkage crack mitigation techniques in soil cement base courses in Louisiana revealed various factors that govern control of reflective cracks in semi-rigid structures *[18]*. The percentage of cement content, base course thickness, polypropylene fibers, pavement interlayers, curing membranes, and curing periods are different factors that were considered in the study. A cement-treated design produced better resistance to transverse cracking when compared to a cement-stabilized design. The cement-treated design used a 12-in. thick base course; whereas, the cement stabilized design used a 8.5-in. thick base course. The target compressive strength of the cement treated design was 150 psi and the cement stabilized design was 300 psi. Fibers and interlayers were found not to be cost-effective to implement in the design. Curing membranes were used to prevent loss of moisture from soil cement during the hydration process, which would cause excessive shrinkage cracks. A curing period of 7 - 30 days was determined to be the best timing as most of the shrinkage cracks occurred in the first two weeks of curing *[18]*.

### Reflective Crack Control Treatments

**Geosynthetics.** “Geosynthetics” is the collective term applied to thin and flexible sheets of synthetic polymer material incorporated in soils, pavements, and bridge decks *[19]*. Geosynthetics are divided into seven major categories: geotextile, also known as paving fabric; geogrid; fiber-glass; geocell; geomembrane; geonet; and geocomposite. Geotextile, geogrid, fiber-glass, and geocomposite have been tested as reflective crack control treatments by acting as reinforcement or as a strain energy absorber. The potential of these products as crack control treatments has been mostly mixed and depends on many factors including the installation procedure and conditions of the existing pavement *[20]*. For a geosynthetic product to outperform regular overlays, the existing pavement should not be severely deteriorated and may not experience excessive movements at the joints with a recommended load transfer efficiency of 80 percent or greater *[20]*. Product manufacturers recommend that a minimum overlay thickness of 1.5 in. should be used and that if the surface has been milled, a leveling course should be applied prior to installing the interlayer system *[21]*.

**Paving Fabrics.** Carey presented one of the first evaluations of paving fabrics in Louisiana *[4]*. Two paving fabrics (a nonwoven polypropylene fabric and a nylon fabric) were applied to highly distressed concrete pavements prior to the placement of HMA overlays to act as strain energy absorbers. A visual survey was conducted periodically for each test section to evaluate the effectiveness of the interlayer system in delaying reflective cracks. A comparison of test sections to control sections indicated that paving fabrics were not effective in delaying or preventing reflective cracking. However, a long-term evaluation of the test sections was recommended to evaluate the potential of the fabrics to provide waterproofing benefits after reflective cracks have appeared.

Storsteen and Rumpca investigated the effectiveness of two geotextile products (Linq Tac-711N and Strata Grid-200) in delaying reflective cracking at the joints when placed on top of a distressed concrete pavement *[22]*. A 1.36-mile test section located on I-29 was divided into 12 segments, each containing 10 joints. Each segment was rehabilitated with Strata Grid 200, Linq Tac-711N, or no geotextile. Three rehabilitation strategies were evaluated: (1) maximum rehabilitation: 4-ft. sections of concrete were removed at the joints and steel bars were then placed and fresh concrete was laid over them; (2) minimum rehabilitation: minor repairs were conducted at the joints; and (3) sawed joints: joints were in the HMA overlay directly above the joints.

Performance of the test sections was monitored for a period of three years. During this period, joint movement, reflective cracking, shoulder cracking, and additional cracks were monitored. A cost analysis was also conducted to determine the benefits of geotextiles in this application. During installation, trucks maneuvering on top of the Strata Grid-200 caused bubbling of the interlayer as it was pulled from tack on the tires. On the other hand, installation of the Linq Tac-711N was successful and straightforward. Results of this study showed that most of the unsawed joints reflected through the asphalt overlay regardless of the use of fabrics. Additional cracks also reflected adjacent to the joints and were monitored. In average, the sections with Strata Grid-200, unsawed, and maximum rehabilitation joints performed poorly with 25 percent of the joints reflecting through the overlay. The sections with no fabric or with Linq Tac-711N had 15 percent of the joints reflecting through the overlay. Results of the cost analysis indicated that the most preferred treatment would be one with no paving fabric, sawed, and with minimum rehabilitation prior to overlay. Linq Tac-711N performed better than Strata Grid-200, but no better than the case with no fabric.

Steen investigated the use of paving fabrics to reduce reflective cracking originating from cement-treated bases *[23]*. The author indicates that the use of cement-treated or lime-treated bases is widely used in pavement construction over weak subgrades. This base type provides a strong foundation for the pavement and helps reducing rutting. It is also a common practice to pre-crack the base in order to reduce thermal movements into this layer. However, even with pre-cracking, this type of base is likely to crack due to its rigidity. In this case, paving fabrics may be used as a stress reliever in order to extend the pavement service life against reflective cracking originating from the base layer. The author discusses some successful applications of this methodology. In one project, a pre-crack cement-treated base was used to increase the pavement structure capacity. However, reflective cracking appeared right after the construction of the first lift of HMA overlay. The use of a tack-coat saturated paving fabric was successful. Two similar projects were also described.

Based on field experience, Steen recommended that the paving fabric be installed between the two lowest layers of asphalt overlay and not directly on top of the cement-treated base. This provides a uniform platform for tack-coat application. Even with the use of fabrics, pre-cracking is recommended as it reduces thermal movement and is inexpensive. Pre-cracking is usually conducted during construction prior to setting of the stabilized material. The use of paving fabrics offers the advantage of obtaining stress-relieving benefits as well as water proofing capabilities. Based on field experience, the use of a paving fabric is comparable to the cost of 0.5 in. of HMA overlay. According to the author, this is cost effective compared to the use of a thick overlay to combat reflective cracking.

Carmichael and Marienfeld synthesized the field performance of paving fabrics in delaying reflective cracking in 16 pavement sections located at 10 different sites *[24]*. The monitored sections made use of paving fabrics over existing PCC pavements as a stand-alone system. Seven of the sites were evaluated for five years while three other sites were evaluated for more than 10 years. In general, performance of paving fabric against reflective cracking was satisfactory. In one section, the overlay lasted more than ten years with only 10 percent reflection in the longitudinal joints and 20 percent reflection in the transverse joints. In another section, the percentage reflection after four years was 36.2 and 42.5 percent in the longitudinal and transverse directions, respectively. The authors pointed out that excessive movements at the joints may reduce the effectiveness of paving fabrics against reflective cracking. Figure 3 shows the installation of a paving fabric. After laying down the material on the tacked surface without any folds or blisters, HMA overlay is placed on top of the material and is carefully compacted using rollers.

**Figure 3**
**Application of paving fabrics *[21]***

**Fiber-Glass Grid.** Marks presented the performance of fiber-glass grid in delaying reflective cracking in four test sections in Iowa *[25]*. The fiber-glass grid was installed on I-35 in which two 1.5-in. lifts of binder course were placed followed by a 1.5-in. wearing surface. Performance was monitored annually for five years by determining the number of cracks that reflected through the layer and by comparing the reinforced sections to the control segments. In one section, the fiber-glass grid was placed directly on top of the concrete pavement while in the three other sections, it was placed between lifts of asphalt mixture. Results of this monitoring showed that the best performer was the section in which the fiber-glass grid was placed directly on top of the concrete pavement, with 43 percent of the joints reflecting after five years. The poorest performer was one section with fiber-glass grid placed between lifts of asphalt concrete with 80 percent of the joints reflecting after five years. Conclusion of this study indicated that the use of fiber-glass grid yields a small reduction in reflective cracking but does not justify the cost of this interlayer system. Figure 4 describes the general structure of a fiber-glass grid.

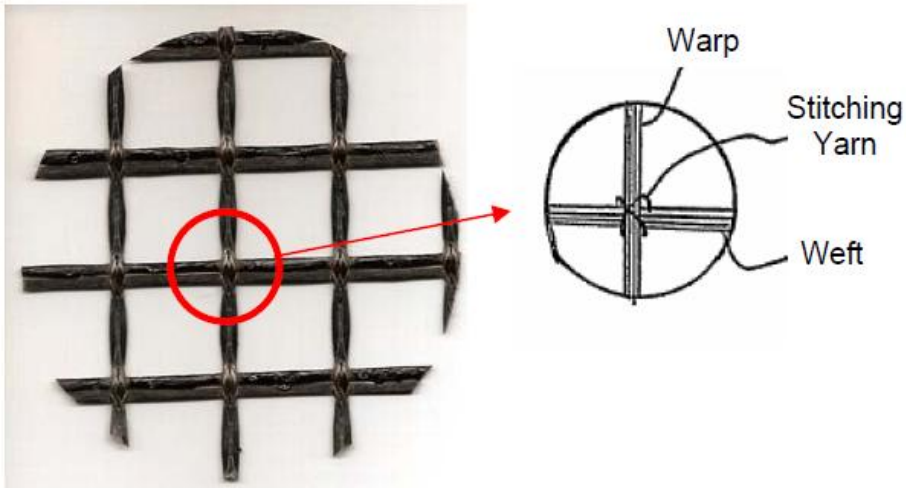



**Figure 4**
**Structure of a fiber-glass grid *[26]***

Bush et al. reported on an experiment conducted by the Oregon Department of Transportation (ODOT) to evaluate five different geosynthetics types including fiber-glass grid *[27]*. The test section was located on US 97 (AADT of 4,899) and consisted of a flexible pavement that suffered from transverse cracking. Prior to rehabilitation, the location and severity of existing cracks was noted; the severity of the cracks ranged from medium to high. Only strip application of the interlayer was evaluated in this study by placing it on top of the existing cracks. A 2.0-in. overlay was then placed over the treated sections. Performance was monitored annually using visual surveys for the period from 1999 to 2007. Results of this study showed that fiber-glass grid was the only interlayer that performed well against high severity cracks. However, the least reflective cracking occurred in the crack fill only test section. Overall, it was concluded that the fiber-glass grid was the best product against high severity cracking with mostly low severity cracking reflecting to the surface.

Chen and co-workers reported on the field performance of various rehabilitation techniques used in Texas including fiber-glass grid reinforcement *[28]*. In one section located on IH 45 (ESALs of $42.2 \times 10^6$), the grid was installed between 2.0 in. of leveling course and 2.0 in. of wearing course. The grid was placed only on top of the joints in strip application. The performance of the grid was inadequate as the section failed prematurely and had to be replaced after one year. Observed distresses included alligator cracking and moisture accumulation at the interface between the overlay and the grid as evident from a Ground Penetrating Radar (GPR) survey. A control section on the same road segment that did not use the reinforcement system performed relatively well. The authors attributed the poor performance of the grid to debonding between the interlayer and the surrounding HMA layers as evident from extracted cores. In another test section in which full-width application of the grid was used, delamination occurred between the grid and the upper HMA overlay. This section had to be replaced one week after placement.

**Composite Systems.** Elseifi and Al-Qadi evaluated the potential of a specially designed geocomposite membrane to delay the reflection of cracks in rehabilitated pavements through strain energy dissipation *[29]*. The geocomposite membrane consisted of a 0.07-in. thick low-modulus polyvinyl chloride (PVC) backed on both sides with 0.028 lb/ft$^2$ of polyester nonwoven geotextile. Results of this analysis showed that the placement of a soft interlayer creates a protective shield around the crack tip, separating the criticality of the stress field in the cracked region from the bottom of the overlay. This study also indicated that a strain energy absorber would only be effective in the crack propagation phase if the crack does not pass through the interlayer and propagates horizontally at the interlayer-existing pavement interface. Monismith and Coetzee referred to this mechanism as "a crack arrest" phenomenon *[30]*. Therefore, the installation of this interlayer is crucial in dictating its performance. If damage or tearing of the interlayer occurs, the effectiveness of the strain energy absorber membrane would be altered.

Deuren and Esnouf presented the performance of a system consisting of a chip seal reinforced with a geotextile membrane to treat severely cracked asphalt pavements *[31]*. The system consists of an ultra-thin overlay on top of a chip seal reinforced with a paving fabric. This system, which is widely used in Australia, consists of a paving geotextile saturated with bitumen and covered with either a single or double bituminous chip seal. A thin overlay (about 0.5 in.) is then applied. The advantage of the described treatment is that it prevents water infiltration into the pavement layers and allows for vertical movement at the cracks due to its high flexibility. This system has been used successfully for over 10 years in over 200 locations in Australia. The authors indicated that the average service life of this system is at least 10 years. A case study of the Monash Freeway is presented. The described treatment has been used on this heavily trafficked freeway. At the time the paper was written, there were no signs of cracking for the past five years.

Dempsey developed a composite interlayer system, known as the Interlayer Stress Absorbing Composite (ISAC), which consists of a low stiffness geotextile at the bottom, a viscoelastic membrane at the center, and a high stiffness geotextile at the top *[32]*. A detailed analysis of the causes of reflective cracking indicated that neither a stress-absorbing membrane interlayer (SAMI) nor a geotextile can completely control this distress when used separately. Through the ISAC system, the low-stiffness geotextile fully adheres to the existing pavement and accommodates large deformation at the joint without breaking its bond with the slab.

The viscoelastic membrane layer acts similar to a SAMI by allowing relative movement between the top and bottom geotextile and between the overlay and the existing pavement. The high modulus geotextile, which forms the upper layer of ISAC, provides reinforcement to the overlay. The ISAC system has been evaluated in the laboratory. The laboratory setup consisted of an HMA overlay placed on top of a jointed PCC slab. A hydraulic actuator was used to simulate thermal loading by opening and closing the joint in the slab. The performance of the ISAC system was compared to an unreinforced overlay and to two interlayer products. Testing was conducted in an environmental chamber set at a temperature of -1.1$^{o}$C. Field performance of the ISAC system was also evaluated in six pavement sections.

Laboratory results indicated that the control section and the overlays reinforced with two typical interlayer products failed after less than 10 cycles of joint movement of 0.07 in. In contrast, the overlay incorporating the ISAC system only cracked at a joint movement of 0.2 in. and did not exhibit any cracking at smaller joint movements with cycles. Field performance of the ISAC system indicates that it is effective in retarding reflective cracking. In one test site (IL 38), while the control sections showed 16 and 18 full-width reflective cracks after less than a year, the section reinforced with ISAC only showed five reflective cracks after six years in service. At another location, while the control section experienced 45 to 50 reflective cracks per kilometer, the ISAC section only indicated three reflective cracks.

**Geogrids.** Hughes and Somers evaluated the field performance of selected interlayer systems (geogrid, paving fabric, and fiber-glass grid) in delaying reflective cracking *[33]*. Two sections were selected for this project. The existing pavement in both test sections consisted of an overlaid rigid pavement. The selected test sites were carrying heavy traffic loads and were subjected to extreme climatic conditions. A control section was available at both locations. In the first test section, the geogrid composite and the paving fabric were installed underneath a 1.5-in. overlay. In the second test section, the fiber-glass grid was also installed underneath a 1.5-in. overlay. No repair was conducted to the existing pavement prior to rehabilitation. In general, installation of the interlayer systems was successful. However, the paving fabric was being picked up by the tires of the haul trucks during installation. This was attributed to the high temperature during installation, which did not allow the tack coat to harden sufficiently. The geogrid composite and the paving fabric were not successful in delaying reflective cracks as they showed comparable performance to the control section. Both the unreinforced and reinforced sections started to show reflective cracks in the third year of the study. The tested fiber-glass grid showed poor performance after the second year although the reinforced section performed better than the control section during the first year.  Although the monitoring process was planned for three years, it was discontinued after the second year as the reinforced section started to deteriorate rapidly and would have been detrimental to the road foundation and the public safety.

As part of the annual highway performance monitoring system (HPMS), two geogrid types were tested on I-10 *[34]*.  Four rehabilitation techniques were compared on a single lane: two geogrid types (one heat sensitive, and the other with greater heat resistance) and two routine rehabilitation processes with a variety of overlay thicknesses.  Results of the field evaluation showed that the section incorporating the heat sensitive geogrid (requiring insulation from a seal coat) "failed shortly after traffic used that lane."  The geogrid with greater heat resistance performed satisfactorily, but was not the best section.

King reported on the construction of a section in Louisiana on Interstate 10 rehabilitated with a geogrid placed between two lifts of HMA overlay *[35]*.  Prior to the HMA overlay, the existing PCC pavement was broken and seated.  The first lift of HMA overlay was tack coated prior to the rolling of the geogrid interlayer.  A total of five rolls of geogrid were placed over the entire two-lane span of the pavement.  After one week of placement of the HMA overlay, the roadway began to ravel excessively and to spall.  Due to the heavy truck traffic, the grid was removed and discarded.  In accordance with the manufacturers' recommendations, the grid was installed in east bound of the roadway and was secured with nails.

**Steel-Reinforcing Nettings.** One of the oldest interlayer systems used in flexible pavements is steel reinforcement, also known as steel reinforcing nettings or steel paving mesh.  This technique, which appeared in the early 1950s, was based on the general concept that if HMA is strong in compression and weak in tension, then reinforcement could be used to provide needed resistance to tensile stresses *[36]*.  At that time, the idea might have been taken from the very successful steel-reinforced Portland cement concrete (PCC).  However, it appears that steel reinforcement was abandoned in the early 1970s after tremendous difficulties were encountered in its installation.  The process reemerged in the early 1980s with a new class of steel reinforcement products in Europe, Table 1.  Many of the earlier problems appeared to have been solved, and satisfactory experiences with the new class of steel reinforcement were reported *[37, 38]*.   The new classes of steel reinforcement nettings are showed in Figure 5.

**Table 1**
**Comparison between the original steel mesh and current steel nettings *[37]***

| Criterion | Original Mesh (1950-1970) | New Mesh (1980-2009) |
|---|---|---|
| Product | Welded wire | Coated mesh |
| Product Shape | Rectangular | Hexagonal |
| Sensitivity to rust | Yes | No |
| Installation | Rigid | Allows horizontal movement |
| Unrolling Process | Manually | Using a roller |
| Creeping of the mesh | Installed loose | Wire tension may be relieved during construction |
| Fixation | Hog rings | Nails or other pertinent method (slurry seal) |
| Cost ($/m$^2$) | 0.20-0.70* | 3.5-10.0^ |

* Cost as of 1970; ^ Upper range includes the cost of a recommended micro-surfacing layer

**Figure 5**
**General configurations of two types of steel reinforcement *[37]***

Evaluation of the new class of steel reinforcement showed that the performance of the overlay was enhanced if slab-fracturing techniques were used to reduce vertical movements at the joints prior to placement of the overlay. It was also concluded that overlay thickness still remains the major factor controlling pavement performance. Among the evaluated test sites was a project in Mont-Saint-Aubert. This site consisted of a highly deteriorated rigid pavement structure with a traffic pattern classified as light to medium; see Figure 6(a). In 1989, steel reinforcement was installed after minor repairs to the existing pavement structure.

A 3-in. overlay was then applied on top of the steel netting.  Figure 6(b) illustrates the same road after 11 years of service (2000).  After 10 years of service, inspections of this site showed a reflective cracking occurrence of only 1 percent.  To date, the new class of steel reinforcement has only been installed in the US in a limited number of experimental sections starting with the Virginia Smart Road in 1999 and several test sites in Pennsylvania, Delaware, and Maryland.  Pioneer work conducted in the evaluation of the new class of steel reinforcement in the US has been conducted by Al-Qadi and co-workers *[39, 40]*.

**(a)** **(b)**

**Figure 6**

**Comparison between a road in Belgium: before repair and 11 years after repair *[37]***

**Stress Absorbing Membrane Interlayer.** SAMI is constructed by placing a seal coat made of rubber asphalt binder (80 percent asphalt cement and 20 percent ground tire rubber) on the surface of the old pavement and then rolling in coarse aggregate chips as shown in Figure 7.  This layer may be used as a stress-relief interlayer.  The main role of the SAMI is to retard crack propagation and improve the tensile strength at the bottom of the overlay due to the presence of the rubber asphalt binder.  It is thought that this interlayer will cause the overlay to behave independently from the underlying structure.  If this hypothesis is correct, higher tensile strains will occur in the overlay, but no reflective cracking will take place. Most of the reviewed literature agreed on the effectiveness of this interlayer to retard reflective cracking *[8]*.

**Figure 7**
**Application of a stress absorbing membrane interlayer *[41]***

Zaghloul et al. reported on the performance of two types of stress absorbing membrane interlayers in California *[42]*. SAMI-R and SAMI-F, which stands for rubberized stress absorbing membrane interlayer and fabric stress absorbing interlayer, respectively, were tested. SAMI-R was designed to provide structural strength to the pavement besides retarding reflective cracks when used with rubberized asphaltic concrete *[42]*.

The construction procedure for SAMI-R involves the placement of asphalt rubber binder followed by the application of aggregates that are precoated with paving asphalt. SAMI-F is placed under dense graded asphaltic concrete. However, there are some factors, which may limit the performance of SAMI if it is not properly constructed. In a hot environment, SAMI should be used carefully as it prevents evaporation of moisture from the subgrade, which would eventually weaken the substructure of the pavement. Stripping of HMA from aggregates would occur if moisture is trapped within the asphalt concrete; this can be prevented by treating the aggregates prior to construction. SAMI-F may become dry and lose its ability to retard reflective cracking if it is used directly on a coarse surface like chip seal or open graded asphalt concrete. SAMI-F should not be used with a high temperature asphalt mix as it would melt the fabric. Better performance was reported when the fabric is saturated with asphalt *[43]*. In the comparison study performed by Zaghloul et al., SAMI-R and SAMI-F performed similarly in terms of predicted service life and rehabilitation stages; however, SAMI-R outperformed SAMI-F in roughness performance *[42]*. Other conclusions from a study performed by Morian et al. in Pennsylvania also support the point that incorporation of SAMI with cold in-place recycling improved pavement service life when compared to normal milling and leveling rehabilitation procedures *[44]*. The use of SAMI increased pavement service life by two years and proved to be cost-effective when compared to conventional leveling and milling procedures *[44]*.

**STRATA® Reflective Crack Relief System.** The STRATA® Reflective Crack Relief System consists of a polymer-rich dense fine aggregate mixture layer that is placed on top of the deteriorated pavement and is then overlaid with HMA *[45]*. As indicated by the manufacturer and owner of this technology (SemMaterials), the use of the STRATA® system delays the appearance of reflective cracking for two years and extends the overlay service life against reflective cracking by five years. The manufacturer recommends using this system on structurally-sound concrete pavement in which any severe distresses should be repaired prior to application. Since its first application in 2001, at least 28 states including Louisiana have tested the STRATA® system with mixed performance. Mechanism of delaying reflective crack by using STRATA® is illustrated in Figure 8.

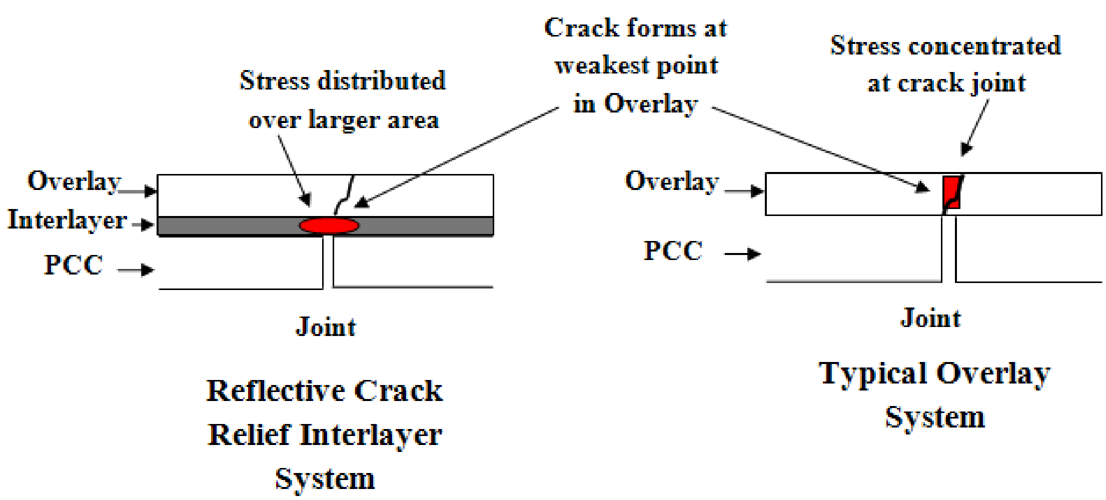



**Figure 8**
**Mechanism of STRATA® in mitigating reflective cracking *[46]***

Bischoff described the evaluation of the STRATA® system in Wisconsin *[45]*. Two separate concrete pavement rehabilitation projects on I-94 were selected. In the first project, a 10-in. jointed reinforced concrete pavement (JRCP) subjected to an average daily traffic (ADT) of 128,000 was overlaid with a 1-in. STRATA® interlayer followed by two 2-in. HMA layers. A control section built without the STRATA® interlayer was constructed with a 1-in. Superpave layer followed by two 2-in. HMA layers. In the second project, a 9-in. JRCP subjected to an ADT of 39,300 was overlaid with a 1-in. STRATA® interlayer followed by a

2.0-in. SMA overlay. The control section as well as the rest of the project consisted of a 2.5-in. Superpave layer followed by a 2-in SMA overlay. The STRATA® mixture was produced and installed using standard paving equipments. Performance evaluation included annual measurement of reflective cracking for four years and ride measurements using the International Roughness Index (IRI).

Results of this study showed that the construction of the STRATA® system was effective with no problems encountered during installation. In the first project, the STRATA® system was able to delay reflective cracking for two years. After the first two years, one STRATA® test section performed similarly to the control section while another STRATA® section performed the best with only 6 percent reflective cracking after four years. Most of the reflective cracks were found on top of the joints. In the second project, one of the control sections performed the best overall. Extracted cores did not validate that the STRATA® system protected underlying materials from moisture infiltration. Based on these findings, this study recommended not using the STRATA® system in Wisconsin.

**NovaChip®.** NovaChip® consists of a thin (3/8 to 3/4 in.) gap graded HMA layer placed on top of a Novabond® membrane, which is a polymer modified asphalt emulsion. This product, which was originally developed in France, is manufactured by SemMaterials in the US. It was originally introduced as a surface treatment for weathered and cracked pavements in order to address the rough texture and the potential for flying chips encountered with chip seal. The application of NovaChip® requires the use of specially designed equipment that places both the Novabond® and the NovaChip® in a single pass. Thin gap-graded hot mix asphalt is placed on a relatively thick polymer modified asphalt emulsion tack coat as shown in Figure 9. Good adhesion, rapid application, and reduced noises were found to be significant advantages of this material *[47]*. A nominal aggregate size of 0.5 in. or less is used in this mix *[48]*. Field performance of NovaChip® in Washington State has been positive when used on top of a deteriorated flexible pavement *[49]*. After six years in service, while the extent of reflective cracking gradually increased over the years, the cracks remained tight. The manufacturer of this system expects a service life ranging from 10 to 12 years. In a report published by National Center for Asphalt Technology (NCAT), Hanson stated that projects in Bucks County and Montgomery County of Pennsylvania reported minor reflective cracks on the surface of the roadway where NovaChip® was used. Similar conclusions were made from projects with NovaChip® in Alabama. Pretreatment of existing joints before application of NovaChip® is strongly recommended. Any cracks greater than 0.25 in. should be cleaned routed and sealed *[50]*.


**Figure 9**
**Novachip paver *[47]***

Louisiana's first experience with NovaChip® was reported by Cooper and Mohammad *[51]*. A test section (SP 407-04-0034) with moderate traffic with an average daily traffic (ADT) of 4,776 was constructed in 1997 in Lafourche Parish on LA 308. Prior to the project, the existing surface was a plant mix seal that was constructed in 1978 on top of 7 in. of HMA. Three sections were constructed and evaluated. In the first section, constructed in 1998, 2.0 in. of the existing HMA was milled with 3.5 in. of overlay placed on top of the milled surface. In the second section, constructed in 1997, a NovaChip® with a thickness of 0.75 in. was installed. In the third section, constructed in 1998, 1.5 in. of the existing HMA was milled with a 3.5-in. overlay placed on top of the milled surface. After six years in service, the NovaChip® was performing satisfactorily with respect to rutting, international roughness index (IRI), longitudinal, random, and transverse cracking. Based on this evaluation, Cooper and Mohammad recommended evaluating the technology in concrete pavements as it may result in cost savings for LADOTD *[51]*.

**Special Purposes HMA Mixtures.** Stone matrix asphalt (SMA) has been used in Louisiana and across the country since the early 1990s. This mixture is currently favored against dense mixtures in highly trafficked routes due to their high resistance to rutting and cracking. Although it is not directly used to resist reflective cracking, a study by the NCAT evaluated the use of this mixture on overlays on top of distressed rigid pavements *[52]*. The use of SMA appeared to reduce reflective cracking, and even when reflective cracks appeared, these few cracks remained tight and were not raveling. This was attributed to the high asphalt content and to the use of polymers, which allow SMA to remain intact adjacent to the cracks. When placed between the distressed pavement and the conventional HMA overlay, this interlayer absorbs a significant portion of the movement at the joints and, therefore, increases the pavement service life against reflective cracking.

**Rubblization.** In order to produce a uniform and high quality base, existing PCC slabs may be rubblized in order to prevent reflective cracking through an HMA overlay *[53]*. Prior to rubblizing the existing surface, the vicinity of the pavement should be investigated for underground utilities, and those utilities must be properly covered to sustain the vibrations produced in rubblization operations. Existing HMA overlay and patches should be removed, and all the water present should be drained off the surface. Rubblization consists of completely fracturing the slabs of a distressed concrete pavement prior to the placement of an HMA overlay. This process eliminates the joints in the distressed pavement. Slab fracturing can be accomplished by crack/seat, break/seat, and rubblization processes. In unstable areas, material should be removed and replaced *[53]*.

In Wisconsin, resonant breakers or multi-head breakers are used for the rubblization process. A smooth double steel drum vibratory roller is used to seat and compact after rubblizing the surface. After rubblizing, the sizes of the particles were inspected for acceptance. In Wisconsin, the maximum size of the particle should be less than 3 in., 9 in., and 12 in. at the top half of the slab, bottom half of the slab, and outside edge of the pavement, respectively. An FWD test should be performed before rubblizing the PCC pavement and after applying the HMA overlay on the rubblized pavement to calculate the deflections. If the average elastic modulus value is greater than 149,969 psi, then particle size distribution throughout the slab should be investigated in detail, and if the value is less than 50,000 psi, then the thickness of the HMA overlay should be increased, considering that the underneath PCC pavement was completely destructed, and the overlay should be applied from the base course *[53]*.

Scullion investigated the effectiveness of rubblization on Interstate 10 in Louisiana using nondestructive techniques *[54]*. Nondestructive data (ground penetrating radar and falling weight deflectometer) were collected from two rubblization projects (Mileposts (MP) 82 to 93 and from MP 93 to MP 103). Based on the results of this analysis, the condition of the test sections was judged to be excellent, validating the benefits of this treatment method in preventing reflective cracking.

**Asphaltic Surface Treatment (Chip Seal).** Chip seal consists of a single layer of asphalt binder, which is covered by a single layer of aggregate *[55]*. Prevention of water intrusion into underneath layers by sealing the fine cracks is the primary purpose of this treatment. The magnitude of tensile stresses should be reduced before they reach the HMA layer. This task is achieved by incorporating a stress absorbing membrane inter-layer consisting of a single or a double chip seal *[56]*. Improved performance in reducing tensile stress by chip seal can be achieved by increasing thickness and flexibility of the interlayer. Thickness can be increased by using a double layer in place of a single chip seal layer, and higher flexibility of the system can be achieved by increasing the binder content in the mix *[56]*. It is important to take measures that prevent potential rutting and shoving problems that would occur in the process of improving the strength of the chip seal layer.

A case study in San Diego tested chip seal over paving fabric and chip seal with a ground rubber modified paving asphalt binder *[57]*. It was concluded that chip seal, when applied over paving fabric, performed well irrespective of crack widths present on the surface of underlying layers. In the US, the practice of installing paving fabric prior to the application of single or double chip seal layer showed little or no reflective cracking for over a period of 20 years and was also found to be cost-effective *[57]*. In warm climate areas like Texas and California, incorporation of fabric improved the life of chip seal by 50 – 75 percent *[57]*. Cost-effectiveness and relatively improved service life were reported to be the important assets of this treatment method.

**Saw and Seal.** Saw and seal is a treatment method used to prevent random propagation of reflective cracking from underlying PCC joints to the top of an HMA overlay. Saw and seal consists of sawing the HMA overlay to create transverse and longitudinal joints at the exact locations of the PCC joints followed by sealing of the constructed joints. Sealing the created joints prevents the infiltration of water and incompressible materials from getting into the underlying layers. Since water infiltration and the possible stripping of HMA accelerate pavement deterioration, sealing the overlay joints properly plays an instrumental role in extending pavement service life *[39]*.

The saw and seal operation should be performed promptly after placement of the overlay but at least 48 hours after paving *[58]*. The success of saw and seal depends on applying the treatment at the exact locations of the joints *[59]*. Prior to the overlay, existing joints on the concrete pavement are located and marked. Joints are then reestablished with chalk after the overlay. These joints are dry cut using a rideable concrete saw. The cuts are cleaned prior to placing the sealant. The cleaning process involves usage of hot compressed air to get rid of all the dust particles, loose debris, and most importantly, moisture that clings to the walls of the groove. For cleaner joints, a sand blaster may be used to remove any remaining debris. The final step is to seal the joints with a low-modulus rubberized sealant *[60]*. Most of the grooves are overfilled from bottom up and then followed by squeegeeing to flush the applied sealant with the pavement surface. It was observed that sealant cools and contracts quickly once the squeegeeing process is completed. Success of saw and seal operations mainly depends on applying the treatment at the exact locations of the joints. Past research studies noted that a saw cut more than 1 in. away from the joint would result in secondary cracking *[61]*.

Researchers at LTRC investigated the effectiveness of several water proofing membranes, sawing, and sealing of joints and use of latex modified asphalt concrete against reflective cracking *[62, 63]*. During installation of the membrane, the HMA overlay appeared to shove during compaction and 6- to 8-in. humps were noticed along the joints. Performance evaluations for the crack control measures were conducted biannually for three years or until extensive reflective cracking occurred. These evaluations included measurements or estimates of crack mapping, rutting (none detected), ride quality, and raveling. Results of the evaluation showed that sawing and sealing over existing transverse joints in a new overlay appears to be the most effective in controlling reflective cracking. In addition, latex-modified HMA was able to control reflective cracking better than conventional HMA.

### Evaluation of Reflective Cracking

**Rolling Dynamic Deflectometer.** There are various methods of quantifying reflective cracking. Non-destructive testing methods are more prominent than destructive testing methods. The rolling dynamic deflectometer (RDD) is a non-destructive apparatus used to analyze pavements for various distresses. It also gives fairly consistent results when compared to the other non-destructive tests available *[64]*. It is assumed that reflective cracks appear at the joints with low load transfer efficiency. The results of the rolling dynamic deflectometer can be used to assess the areas with low load transfer efficiency and re-treat them *[64]*.

It is always necessary to assess a loss of load transfer at the joints before selecting a joint rehabilitation technique. The rolling dynamic deflectometer is preferred over the falling weight deflectometer (FWD) because it is capable of evaluating the performance of every joint and crack in a continuous manner; whereas the falling weight deflectometer evaluates the performance at discrete locations. Identifying the locations with maximum risk of reflective cracking and determining locations, which are in need of full depth repairs are the reasons for using a rolling dynamic deflectometer. RDD also allows for monitoring the effectiveness of rehabilitation treatments. RDD provides a continuous deflection profile of the pavement; therefore, the ratio of deflection of loaded to unloaded sections is determined from the profile, hence, determining the load transfer efficiency. The data gathered from the rolling dynamic deflectometer are used to divide the pavements into zones of highest preference to lowest preference of rehabilitation. Results are also used to determine the thickness of the overlay based upon the conditions of the existing pavement *[64]*.

**Wheel Reflective Cracking Apparatus.** The wheel reflective cracking tester is used at the design phase, unlike the RDD, which is used in the performance phase. The structural capacity and the severity of cracks can be monitored using this equipment. The wheel reflective cracking apparatus consists of two plates, one of which is fixed while the other one is movable. An asphaltic concrete slab is placed on these two plates, which are spaced approximately at a distance of 0.4 in. The extreme ends of these plates are supported by shoulders; whereas, the closer ends with a space of 0.4 in., which acts as joint, are allowed to rest on a rubber pad. A ball and plate system is provided on the rubber pad to simulate vertical joint movements. Dynamic force is created by a moving wheel on the top of slab whose operation can be controlled using a computer. The moving plate simulates movement of underlying PCC slabs, which occur in the field due to dynamic and thermal stresses. The wheel reflective cracking device is capable of simulating distresses like the rigidity of asphalt at low temperatures, differential horizontal, and vertical movements, simultaneously. This test assists engineers in selecting asphaltic materials that may resist reflective cracking *[65]*.

**Overlay Tester.** The effectiveness of geosynthetic materials in mitigating reflective crack propagation can be evaluated using an overlay tester. This overlay tester was designed by Lytton and co-workers *[66]*. This equipment was then updated and is able to facilitate simple/rapid performance-related tests. One of the advantages of this updated version is a comparatively small specimen can be prepared and tested. This test is run to predict the reflective cracking resistance of HMA. Using this testing machine, it was found that higher binder content would significantly reduce reflective crack initiation. The overlay tester has performed significantly well in simulating field conditions. Assurance of adequate crack resistance characteristics of the designed mixture can also be predicted using the overlay tester *[66]*.

### Flexible Overlay Design for Rigid/Composite Pavements against Reflective Cracking

An overlay design procedure involves the prediction of the timing of reflective cracking, traffic and environmental conditions, analysis reports from various non-destructive testing equipment (FWD, GPR, RDD, etc.), thickness of the HMA required and reflective crack mitigation methods used prior to the application of the overlay *[67]*.

The joint spacing or slab lengths have a complex effect on reflective cracks. The timing of occurrence of reflective cracks, which have similar joint spacing or slab lengths, varied in different places *[67]*. Therefore, the most appropriate joint spacing to mitigate reflective cracks is unclear, although a joint spacing of less than or equal to 15 ft. has been used by most of the states and resulted in a positive outcome to a significant extent. Considering the overlay thickness design, nearly 20 states use the 1993 AASHTO design guide and DARWIN software. However, six states utilize their own policy for designing the overlay thickness and this depends upon historical data, traffic conditions, environmental conditions, and the geometry of the pavement. Materials used in HMA design depend upon the state policy; many states prefer a 0.38-in. Superpave mix over a 0.5-in. Superpave mix or a 0.5-in. Superpave mix over a 0.75-in. Superpave mix. The binder is selected on the basis of recommendations by Long Term Pavement Performance (LTPP) Bind or with respect to the PG binder based on the temperature in that area *[67]*.

A study was performed by Sousa et al. to consider reflective cracking in the design of overlay using mechanistic-empirical concepts *[68]*. The proposed design methodology used moduli and thickness of existing pavement layers, which are determined from FWD backcalculation methods. The maximum and minimum air temperatures that pavement would experience should be calculated prior to the design. Field adjustment factors and temperature adjustment factors (mix-dependent) should be calculated by utilizing proposed models. Flexural fatigue tests are performed to calculate modulus and flexural fatigue life of materials to be used in the design. Mechanistic models were proposed by the research team to calulate design ESALs and to predict the performance of the overlay. All the models that were proposed by the research team involved finite element method and were successful in developing a statistic mathematical model to determine the thickness required to prevent reflective cracking. This model strongly recommends the usage of rubber-modified asphalt to increase the life of pavement in terms of fatigue and reflective crack propagation *[68]*.

Vanelstraete et al. proposed an overlay design method based on the 3D finite element simulation. Vanelstraete et al. suggested the use of design charts to evaluate the substantial saving in overlay thickness when steel reinforcement was used on top of rigid pavement *[38]*. Shear strain at the bottom of the overlay (mainly responsible for slab rocking) and surface deflection were used as bases of comparison. The followed simplified approach seems promising, since the finite element method is a complex and costly analysis tool that cannot be used in routine design. However, for successful implementation, the finite element model should first be calibrated based on experimental measurements, and a parametric study should then be performed using the calibrated models to evaluate the effects of the different design parameters *[38]*.

**Cost-Effectiveness**

Buttlar et al. investigated the cost-effectiveness of paving fabrics in delaying the reflection of cracks based on the field performance of 52 test projects in Illinois *[69]*. All projects consisted of rigid pavement systems overlaid by multiple HMA layers over the life span of the structure. Both strip and area treatment rehabilitation strategies were investigated with consideration of eight replicates for each combination of treatment and climatic conditions. Some combinations were not available to complete the entire factorial design; the distribution of the 52 projects was 26 strip, 17 treatment areas, and 9 control sections. Overall, while strip applications improved pavement serviceability by 1.1 years, area applications improved pavement serviceability by 3.6 years.

Abadie evaluated the cost-effectiveness of fiber glass-grid in two projects in Louisiana *[70]*. The first project (SP 056-03-0025) was located on LA 31 in St. Martin Parish and was monitored for five years from September 1996 to December 2001. The second project (SP 013-09-0035) was located on US 190 in Tangipahoa Parish and was monitored for seven years from November 1994 to November 2001. Pavement designs in these two projects as well as the measured traffic volume (AADT) at the beginning of the monitoring period are presented in Table 2.

**Table 2**
**Pavement test sections evaluated by abadie *[70]***

| State Project | Test Section | Pavement Design | | | | Traffic |
|---|---|---|---|---|---|---|
| | | Wearing Course | Binder Course | Leveling Course | Original Pavement | |
| SP 056-03-0025 | Control | 1.5 in. | 1.5 in. | N/A | HMA with C.T. Base | 8,900 |
| SP 056-03-0025 | Glasgrid | 1.5 in. | 1.5 in. | N/A | HMA with C.T. Base | 8,900 |
| SP 056-03-0025 | Glasgrid | 1.5 in. | 1.5 in. | N/A | HMA over JCP | 8,900 |
| SP 013-09-0035 | Control | 1.5 in. | 2.0 in. | 2.0in | JCP | 6,000 |
| SP 013-09-0035 | Glasgrid | 1.5 in. | 2.0 in. | 2.0in | JCP | 6,000 |

Results of this analysis indicated that while fiber-glass grid performed relatively well in one project (SP 056-03-0025) by reducing reflective cracking by up to 50 percent in five years as compared to the control section, it performed similarly to the control section in the second project (SP 013-09-0035). However, even by improving the performance of the overlay against reflective cracking, the cost of the interlayer system will almost double the cost of a 3-in. overlay *[70]*.

A study was conducted by Baek et al. to evaluate the cost-effectiveness of steel reinforcement nettings in preventing reflective cracking on composite pavements. Conclusions from life-cycle cost analysis proved that the initial cost of construction was greater in the case of reinforced overlay when compared to conventional overlay. This analysis proposed a two-time overlay in a life span of 50 years for a reinforced overlay and a four-time overlay for a conventional overlay. This would eventually save expenditures by 7 percent *[71]*. These savings would be much higher if costs associated with routing maintenance like crack sealing were considered. HMA-to-steel netting cost ratio is a sensitive factor that affects the profit percentage; if the ratio is higher, the benefits are higher and vice versa *[71]*.

## Construction Specifications for Various Treatments in the State of Louisiana

**Asphaltic Surface Treatment (Chip Seal).** Asphaltic Surface Treatment (AST), also known as chip seal, is primarily used to improve surface friction and seal cracks and to reduce the rate of oxidation of surface mixtures. It is also used as an interlayer to delay or reduce propagation of reflective cracks *[72]*. Projects, which had chip seal as an interlayer, were considered for detailed analysis in this study. Hot modified asphalt or a specified cold emulsion could be used as AST in accord with section 507 *[72]*. A power asphalt distributor, a computer-operated height adjustable spray bar, and spray nozzle machine is used to spray asphalt at the required rate. It should be capable of adjusting within ±0.02 gallons per square yard of the specified rate of distribution. This machine should be calibrated in accordance with ASTM D 2995 at least 12 months prior to usage.

Asphaltic surface treatment cannot be placed on a surface when the air or surface temperature is less than 60°F. AST as an interlayer can be constructed during any month; however, there are some limitations to apply AST as a surface treatment based upon hot or cold application. Prior to the application of AST, all potholes and surface depressions should be repaired. Pavement should be examined by the engineer for any moisture content beyond allowable limits before applying the treatment. The AST interlayer can be applied on a raw or stabilized base, on a milled surface, between lifts of asphalt, or over existing Portland cement concrete pavement. A five-day rest period should be allowed before placing asphaltic overlay over AST interlayer; however, hot applied interlayer may be overlaid immediately. The surface should be properly compacted, rolled, and broomed for any loose aggregates the next morning before allowing traffic on to the roadway. In Louisiana, typical AST interlayers are termed as Type E *[73]*.

**Roadway Reinforcing Mesh (Fiber-Glass Grid).** Roadway reinforcing mesh, also known as fiber-glass grid, is used to reinforce a complete road system (full width and full length of each travel lane). It is placed as an interlayer prior to an HMA overlay of concrete pavements with the sole purpose of retarding reflective cracks. A glass fiber strand grid, which satisfies the following characteristics, would be approved:

- Tensile strength - 560 lb/in x 560 lb/in component strand strengths, ASTM D 6637.
- Area weight - 11oz/yd$^2$, ASTM D 5261.
- The elongation at break shall be less than 5%, ASTM D 6637.
- The melting point shall be above 425°F, ASTM D 276.
- The roll length by width shall be 327 ft. x 5 ft.
- The grid size shall be 0.5 in. x 0.5 in.
- The mesh shall have pressure-sensitive adhesive backing, with sufficient bond to allow normal construction traffic and paving machinery operations.

Prior to the installation of roadway reinforcement mesh, the surface should be repaired, cracks must be sealed, and potholes must be filled. The surface temperature should be between 40°F and 140°F. It is important to lay down the roadway reinforcement mesh without any ripples; this can be achieved either by laying the material by hand or by any mechanical means. Any ripples that are present should be pulled tight, or in some cases the grid should be cut and laid flat. A rubber-coated drum roller or a pneumatic type roller should be used to roll the mesh, which will eventually activate the adhesive. A tack coat was applied on top of the grid at a minimum rate of 0.06 gal/yd$^2$ to obtain additional adhesion. Transverse joints should be overlapped by 3 to 6 in. and longitudinal joints by 1 to 2 in.; however, usually the mesh is laid in a continuous manner, which would eventually eliminate transverse joint overlapping. The asphaltic overlay on roadway reinforcement mesh should be at least 1.5 in. thick and should be applied on the same day when the mesh is placed. Similar specifications are applicable to any geosynthetic fabrics.

**Sawing and Sealing of Joints.** Saw and seal consists of sawing the overlaid asphaltic concrete pavement to create transverse and longitudinal joints at the exact locations of underlying PCC joints followed by sealing of those constructed joints. Success of saw and seal depends on applying the treatment at the exact locations of the joints. Prior to overlay, existing joints on the concrete pavement should be located and marked accurately by placing a hub with a tack even with the ground at each edge of shoulder. In Louisiana, the saw cut should be a minimum of 1/8$^{th}$ in. wide by 1 in. deep. The overlay should be thoroughly cooled before sawing the joints, and it should be completed within three calendar days for each layer of overlay. Once the joints are properly established and sawed until the bottom layer, these saw cuts should be cleaned by blowing compressed air to remove slurry, dirt, and water. Contaminated joints may be subjected to re-cleaning upon the engineer's judgment. Cross linked polyethylene or 3/16 in. polyolefin foamed rod may be used as a backer material. A low modulus rubberized sealant is used to seal the created joints, which should be performed as soon as possible after cleaning the joints and before allowing the traffic. The sealed joints are left undisturbed by not allowing any traffic till it is tack free *[74]*.

**Stress Absorbing Membrane Interlayer.** SAMI is also known as the asphalt rubber stress absorbing membrane interlayer. This treatment consists of a single application surface treatment using an asphalt-rubber binder. Ground recycled rubber used in this material should meet the requirements presented in Table 3 when tested in accordance with ASTM C-136.

**Table 3**
**Specifications for SAMI**

| Sieve Sizes | Percent Passing |
|---|---|
| No. 8 | 100 |
| No. 10 | 95-100 |
| No. 16 | 40-60 |
| No. 30 | 0-20 |
| No. 50 | 0-10 |

Granulated rubber particles should not be greater than 3/16 in. with a specific gravity of 1.15 ± 0.05. The percentage of granulated rubber in the asphalt rubber mix shall be 23% ± 3 by weight of the total mixture. Temperature conditions of asphalt cement may be within the specified range of 350 to 425°F when mixing granulated rubber. The lower limit of the mix is 350°F during the reaction period. In case of delay of the application of the mixture, it is allowed to cool and reheated slowly up to a temperature not greater than 350°F just before application. This mix is applied at a temperature of 325 to 400°F at a rate of 0.5 to 0.65 gallons per square yard. After at least one hour from application of an asphalt rubber stress absorbing membrane interlayer, the sweeping process should be initiated to clean up any loose aggregates *[75]*.

**High Strain Asphalt Mixture-Reflective Crack Relief Interlayer (STRATA®).** High strain asphalt mixture is also known as STRATA®. This interlayer system is a highly elastic, impermeable hot mix layer primarily designed to reduce reflective cracking from underlying Portland cement concrete. On a prepared surface, the interlayer is directly placed using conventional rollers and pavers. Once the reflective crack relief layer is placed, it should be overlaid with an HMA layer within five construction days. High strain asphalt mixture consists of asphalt PG 76-22 and blended aggregates. Natural sands, crushed fines, and screenings, which meet certain criteria, comprise of blended aggregates. Hveem stability testing and flexural beam fatigue testing is performed on the prepared mix. The temperature conditions under which the interlayer could be placed are either the air temperature or the surface temperature should be at least 50°F and rising. The reflective crack relief interlayer is not placed on wet surfaces to avoid blisters. The average thickness of the reflective crack relief interlayer should be 1 in. with a tolerance of + 0.25 in. Overlap length should be at least 6 in. for longitudinal joints. Once the reflective crack relief interlayer is applied, it should appear to be tight and black. A roadway may be opened to traffic either after placement of overlay on the interlayer or when the temperature of the interlayer falls below 160°F *[76]*.

# OBJECTIVE

The objective of this study was to evaluate and to compare different reflective cracking control treatments by evaluating the performance, constructability, and cost-effectiveness of pavements built with these methods across the state. Results of this analysis assessed the benefits of these crack control techniques in terms of performance, economic worthiness, constructability, and long-term benefits. Based on the findings and the results of this project, recommendations for cost-effective control of reflective cracking were made.

# SCOPE

State practices for control of reflective cracking were identified through district surveys and by reviewing the LADOTD databases and PMS data.  Projects built with different crack control treatment methods were identified.  The treatment methods that are evaluated in this study are fiber-glass grid, saw and seal, asphaltic surface treatment (AST - chip seal) as a crack relief interlayer, SAMI, fabrics, and STRATA®.  However, there was an insufficient number of projects for the stress absorbing membrane interlayer, paving fabrics, and the high strain asphalt reflective crack relief interlayer to allow for drawing conclusions on the cost-effectiveness of these treatment methods.

# METHODOLOGY

Current practices used in Louisiana to delay reflective cracking in rehabilitated pavements were identified. This task was achieved by first surveying all the district offices in Louisiana. The Content Manager Tool on the LADOTD Intranet Web site was also reviewed to identify other treatment methods, which were not reported in the district surveys. This step was followed by identifying the projects in which different treatment methods were used. The basic requirement for a treatment to be considered as a reflective crack prevention technique in this study is that it should be applied over an existing concrete layer and below an asphaltic overlay or in between asphalt layers on top of PCC. The performance and cost-effectiveness of the different treatment methods were assessed by analyzing performance data obtained from the LADOTD pavement management system for the period ranging from 1995 to 2009. The Reflective Cracking Index (RCI) and the Pavement Condition Index (PCI) were the two parameters used to assess the performance of the pavement sections. A simplified economic evaluation was then performed on all the projects that were selected for detailed analysis. The adopted economic approach calculated the total annual cost (TAC) per mile for each pavement section by dividing the total cost of the project, obtained from bid items, by the performance service life in years and the length of the section. Comparison was then established between the total annual cost of the treated and untreated segments to determine cost effectiveness.

## Survey of Current Practices in Louisiana

The objective of the survey was to identify current practices used in Louisiana to delay reflective cracking in rehabilitated pavements. To achieve this task, the research team sent a project identification survey card to district engineers, Figure 10. The project identification survey card collects information on the type of crack control treatments used (i.e., current and past practices in Louisiana), type, and age of the pavement structures, rehabilitation methods, traffic volume, performance prior to and after rehabilitation, cost data, location of the project, and whether an untreated segment, which could be used as a control section, was available. The project identification card was considered as a first step in collecting relevant performance and cost data. This survey also informed the districts with the type of data that the researchers were trying to collect and established a channel of communication.

## PROJECT IDENTIFICATION CARD

For each project in your district in which a reflective crack control treatment was used, please provide the following information.

**Project Number:**

**Project Location:**

---

**Reflective cracking control treatment method:**

---

**Date of Application of the treatment:**

---

**Distresses prior to application of the treatment method:**

---

**Did additional rehabilitation actions were taken after application of the treatment?**

---

Performance Data Available: Yes No

Cost Data Available: Yes No

Untreated segment: Yes No

Pavement Design (prior to control treatment application):

Overlay Thickness and Mix Type:

Traffic Volume (AADT or ESALs per year):

Road Class:

Interstate

Other Principal

Arterial

Secondary

**Figure 10**
**Project identification card sent to the districts**

The project identification card was sent to the nine districts in Louisiana. While the initial response to the survey was relatively low, numerous attempts made through LTRC helped increase the rate of response to the survey. Seven out of the nine districts responded. Despite numerous attempts, researchers could not establish a channel of communication with Districts 2 and 3. To address this limitation and in order to identify as many pavement sections as possible, information available in the mainframe through the Tracking of Projects System (TOPS) was utilized. Researchers also identified a large number of projects through communication with the LTRC staff that participated in past research studies dealing with reflective cracking. Details about the identified sections were found through the Content Manager, which includes information about the construction and design processes, cost data, traffic, and project schedule. Based on this approach, a total of 375 pavement sections were identified with a summary presented in Table 4. Due to the large amount of data compiled from the different sources, collected information is organized in a Microsoft Access database.

**Table 4**
**Survey of crack control treatment methods across the state**

| **Treatment Method** | **Number of Projects** | **Date of last Use** |
|---|---|---|
| Fiber-Glass Grid (Area Application) | 38 | 2008 |
| Fiber-Glass Grid (Strip Application) | 1 | 2003 |
| Paving Fabric | 4 | 2000 |
| Saw and Seal | 80 | 2008 |
| Cold-in Place Recycling | 1 | 1995 |
| Hot-in Place Recycling | 2 | 1992 |
| Asphalt-Surface Treatment (AST) / Chip Seal | 161 | 2008 |
| Stress-Absorbing Membrane Interlayer | 35 | 1993 |
| STRATA® | 6 | 2008 |
| NOVACHIP® | 45 | 2008 |
| Tru-Pav Fiberglass Fabric | 1 | 2005 |
| **Total** | **375** | **N/A** |

## Identification of Sections in the State for Detailed Analysis

District surveys were helpful to a limited extent in identifying pavement sections with reflective crack relief treatments. Using the Content Manager on the LADOTD Intranet Web site, a vast inventory of projects with basic information was prepared. The Mainframe database was also used to obtain more details for each project. The criteria for projects to be selected for detailed performance and economic analyses were:

(1) Performance data for a minimum of three years should be available; and

(2) an untreated segment should be available adjacent to the treated section.

District and treatment method classifications were conducted separately, and a detailed database was prepared to organize collected information. Every project in the inventory was verified in the Mainframe database for the date of construction, location, and traffic details. These data were critical for selecting pavement sections for detailed performance analysis. After determining the date of construction, the project was scrutinized to check the first requirement for analysis. An untreated segment was identified based on log mile information. Video footage of every highway is available in the LADOTD database. These videos were reviewed in order to identify the log miles before and after the treated section. If any road section appeared similar in design to the treated section, then that portion of roadway was considered to be the untreated section. In some cases, pavements that had sufficient performance data for analysis were ruled out due to the presence of a concrete or a flexible pavement at both ends of the treated section.

Once the design comparison was visually confirmed, these sections were further scrutinized based upon detailed design data. Plans of all the roadways are available on the LADOTD Intranet Web site. These plans were reviewed for both the treated and untreated sections for the following details: presence of a concrete pavement underneath the asphalt overlay and presence of a treatment between the concrete and HMA overlays. If a project did not meet any of the requirements, it was not considered for detailed performance and cost analysis.

### Identification of Control/Untreated Sections

After identifying the date of construction and log mile limits of the treated sections, videos of the road sections were reviewed to locate the untreated sections. Videos are classified based upon district and route. The type of road section present either for one mile before the beginning log mile of the treated section or for one mile after the end log mile was observed. If it was not a rigid pavement, further details were investigated to identify if it had any treatments or if it was a flexible pavement. Only one mile was selected as it was assumed that climatic, traffic, and other construction details would be similar for both treated and untreated sections, which would allow for a valid comparison in the analysis.

The roadway design within log mile limits in the untreated area was reviewed for the presence of concrete pavement underneath the HMA overlay and it was also verified for the presence of any other treatment methods. After all the requirements were satisfied, that pavement segment was considered the best untreated section for that particular treated section. The untreated segment could be located either before or after the treated section. The only limitation of this approach is that in some cases, the construction dates of the treated and untreated sections were different as these pavements were not constructed for research purposes; however, this limitation did not affect the analysis because comparison was established relatively based on the overall pavement service life regardless of the year of construction.

**Description of Projects Selected for Detailed Analysis**

As mentioned in the previous sections, different criteria were used to select projects for detailed analysis.  Fifty projects were analyzed in total, which included 13 projects for roadway reinforcement mesh (fiber-glass grid), 15 projects for saw and seal, 12 projects for asphaltic surface treatment (chip seal), three projects for SAMI, 3 projects for paving fabric, and 3 projects for high strain asphalt mixture-reflective crack relief interlayer (STRATA®). As shown in Figure 11, these projects were located in different climatic regions in the state. A comprehensive database, which was classified by treatment type and district location, was created to list all the projects, (including the ones that were not considered for detailed analysis), which were treated with various reflective crack prevention techniques to assist future research projects dealing with related topics.  A list of identified pavement sections is presented in the Appendix.

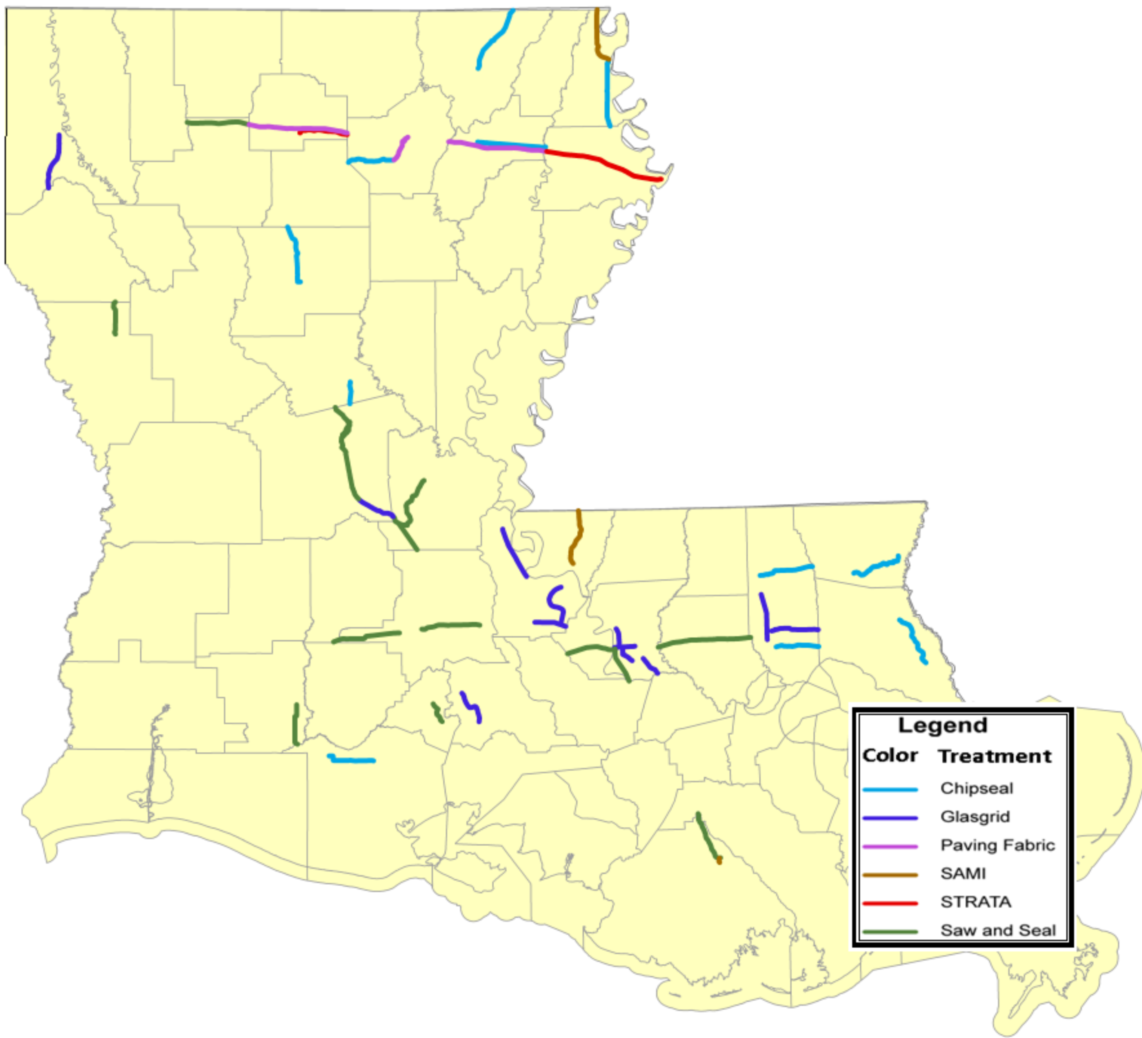



**Figure 11**
**Illustration of projects selected for detailed performance analysis and cost analysis**

A list of projects that were selected for detailed analysis is provided in Tables 5 (a), (b), (c) and (d). Projects 261-04-0021 and 067-09-0038 had multiple treatments incorporated. Project 261-04-0021 was treated with chip seal from log miles 4.6 to 6.6 and treated with STRATA® from log miles 2.9 to 4.6. Project 067-09-0038 was treated with paving fabric and sand anti-fracture interlayer in the south bound and north bound directions, respectively.

**Table 5**
**Lists of projects selected for detailed performance and cost analysis**

**(a)**

| Project No. | Treatment | Route | Construction Date |
|---|---|---|---|
| 055-04-0017 | Chip seal | LA 14 | October-03 |
| 002-03-0039 | Chip seal | US 80 | October-04 |
| 016-05-0028 | Chip seal | US 165 | October-04 |
| 020-08-0025 | Chip seal | US 65 | May-04 |
| 023-05-0039 | Chip seal | US 167 | November-04 |
| 261-04-0021 | Chip seal | LA 22 | December-04 |
| 261-04-0019 | Chip seal | LA 22 | September-98 |
| 058-01-0024 | Chip seal | LA 41 | March-05 |
| 047-01-0040 | Chip seal | LA 16 | October-03 |
| 279-04-0022 | Chip seal | LA 60 | November-04 |
| 067-08-0014 | Chip seal | LA 34 | November-03 |
| 015-03-0023 | Chip seal | US 165 | September-04 |

**(b)**

| Project No. | Treatment | Route | Construction Date |
|---|---|---|---|
| 410-01-0029 | Fiber-glass grid | LA 428 | January-99 |
| 056-03-0025 | Fiber-glass grid | LA 31 | October-96 |
| 025-08-0054 | Fiber-glass grid | US 171 | October-03 |
| 007-08-0030 | Fiber-glass grid | US 61 | January-05 |
| 013-04-0036 | Fiber-glass grid | US 61 | March-00 |
| 019-01-0031 | Fiber-glass grid | US 61 | October-02 |
| 008-02-0029 | Fiber-glass grid | US 190 | November-03 |
| 052-01-0017 | Fiber-glass grid | LA 1 | November-04 |
| 052-03-0026 | Fiber-glass grid | LA 1 | October-02 |
| 013-09-0035 | Fiber-glass grid | US 190 | January-95 |
| 017-04-0043 | Fiber-glass grid | US 51 | August-00 |
| 258-02-0016 | Fiber-glass grid | LA 427 | June-97 |
| 008-08-0028 | Fiber-glass grid | US 71 | January-03 |

**(c)**

| Project No. | Treatment | Route | Construction Date |
|---|---|---|---|
| 065-04-0034 | Saw and Seal | LA 24 | June-95 |
| 004-01-0036 | Saw and Seal | US 90 | July-95 |
| 012-11-0034 | Saw and Seal | US 190 | August-02 |
| 012-13-0088 | Saw and Seal | US 190 | June-95 |
| 451-04-0030 | Saw and Seal | I-20 | February-98 |
| 054-05-0017 | Saw and Seal | LA 26 | July-00 |
| 008-07-0028 | Saw and Seal | US 71 | January-03 |
| 008-09-0052 | Saw and Seal | US 167 - B | September-02 |
| 015-01-0046 | Saw and Seal | US 165 X | November-00 |
| 023-01-0043 | Saw and Seal | US 167 | May-95 |
| 033-01-0027 | Saw and Seal | LA 29 | November-99 |
| 035-02-0021 | Saw and Seal | LA 175 | September-00 |
| 414-01-0021 | Saw and Seal | LA 30 | May-96 |
| 450-08-0037 | Saw and Seal | I 10 | March-98 |
| 454-02-0026 | Saw and Seal | I 12 | June-01 |

**(d)**

| Project No. | Treatment | Route | Construction Date |
|---|---|---|---|
| 020-09-0025 | SAMI | US 65 | March-91 |
| 413-30-0010 | SAMI | LA 311 | February-92 |
| 019-05-0024 | SAMI | US 61 | October-93 |
| 067-09-0038 | Paving Fabric | LA 34 | April-01 |
| 451-07-0051 | Paving Fabric | I-20 | November-03 |
| 451-05-0086 | Paving Fabric | I-20 | April-98 |
| 451-08-0060 | STRATA | I-20 | November-03 |
| 001-08-0035 | STRATA | US 80 | March-04 |
| 261-04-0021 | STRATA | LA 22 | December-04 |

## Analysis Methodology

Pavement performance data were obtained from the LADOTD pavement management system for the period ranging from 1995 to 2009. The PMS data were based on pavement condition measurements that were collected once every two years using the Automatic Road Analyzer (ARAN®) system, which provides a continuous assessment of the road network. The Reflective Cracking Index (RCI) and the Pavement Condition Index (PCI) were the two parameters used to assess the performance of the pavement sections. Videos of different roadways were available from year 2000 to 2009 for fiber-glass grid projects, with years 2007 and 2009 available for all other projects. As presented in the next section, these videos were utilized in calculating RCI and to identify double cracking and additional cracking at the joints. PCI data were available from the year 1995 to 2009 for all the projects. As presented in the subsequent sections of this report, a change in the PCI trend since the year of construction was used to predict the service life of the pavement. Different trigger values were considered in indentifying the need for rehabilitation. The number of years at which the pavement needs rehabilitation after construction was considered to be the critical factor to calculate the service life of the pavement.

### Reflective Cracking Index

RCI represents the percentage of joints that reflect the pavement surface. This parameter was calculated by counting the number of reflected cracks at the joints. The Visidata software developed by Roadware, Inc., was instrumental in the analysis of the pavement sections in order to calculate the RCI as it provided various digital views of the pavement structure, see Figure 12. Videos were available on different servers for all the districts. Unfortunately, the server holding videos for years 2000, 2003, and 2005 crashed after analyzing the fiber-glass grid projects. This incident only allowed the calculation of RCI for the years 2007 and 2009 for the remaining projects in other treatment categories.


**(a)** **(b)**

**Figure 12**
**Pavement imaging and the detection of reflective cracking**

Videos of the roadway sections are stored in the server and are classified by districts. To determine the number of joints that reflected on a specific road segment, video crack surveys were reviewed, using the Visidata software. This software links video pavement imaging with global positioning and performance data. To ensure that only reflected cracks are counted and that other transversely manifested cracks are not included, the first joint location was identified near the begin log mile; the location of the following joint was then identified by adding the joint spacing to the log mile. This location was examined for reflective cracking and counted as one reflective crack. This process was then repeated until the end of the pavement section. The RCI for a given road section was calculated as follows:

$$\mathbf{RCI}\ (\%) = \frac{\#\mathbf{RC}}{\#\ \mathbf{J}} * \mathbf{100} \qquad (2)$$

where,

RCI = Reflective Cracking Index,

RC = No. of cracks that reflected, and

J = Total No. of joints on the road section (length of road ÷ joint spacing).

**Joint Spacing.** Joint spacing of underlying PCC pavement played a vital role in calculating the RCI of a pavement section. In order to identify the joint spacing of the roadway, Ground Penetrating Radar (GPR) testing was performed on one of the sites. The output from the GPR survey provided the value of joint spacing used in the underlying PCC pavement. Due to testing constraints, the GPR survey was only conducted on a single project. Further discussions with PMS engineers and design engineers at LADOTD headquarters supported the assumption of a joint spacing value of 20 ft. for all pavement sections. Figure 13 illustrates the image of the road section obtained from the GPR survey, showing various underlying layers. A difference in the image pattern was observed at a regular interval of 20 ft. The reason for such a change in pattern was identified as the change in density levels of the materials. The change in densities occurred due to the presence of concrete throughout the slab and a presence of air at the joints.

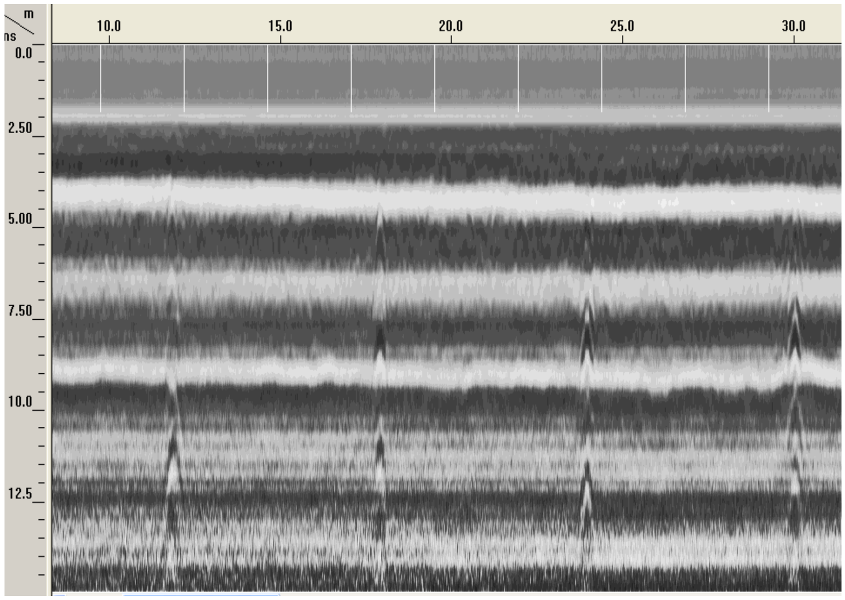



**Figure 13**
**Image of roadway obtained from GPR survey**

**Working with Visidata 215.** Figure 14 shows the main interface of the Visidata software application. Various inputs were used depending upon the location, route, and log mile limits of each project. The speed of the video is selected by the user by dragging the speed bar on the top right of the controller. Other features are similar to that of a video player: the play buttons may be used to play forward or backward; the forward or rewind buttons may be used to move one slide forward or one slide backward (0.005 miles at a time); and the skip buttons may be used to move the frames backward or forward by 0.1 mile at a time. These features were used to identify double cracking for the saw and seal projects.

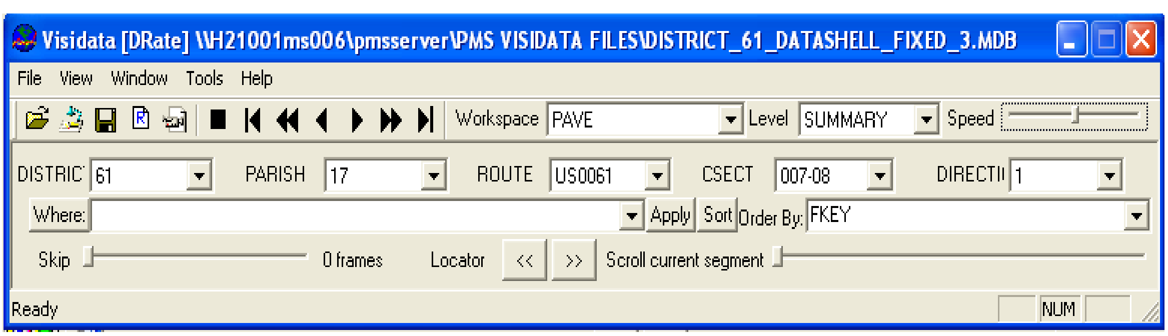
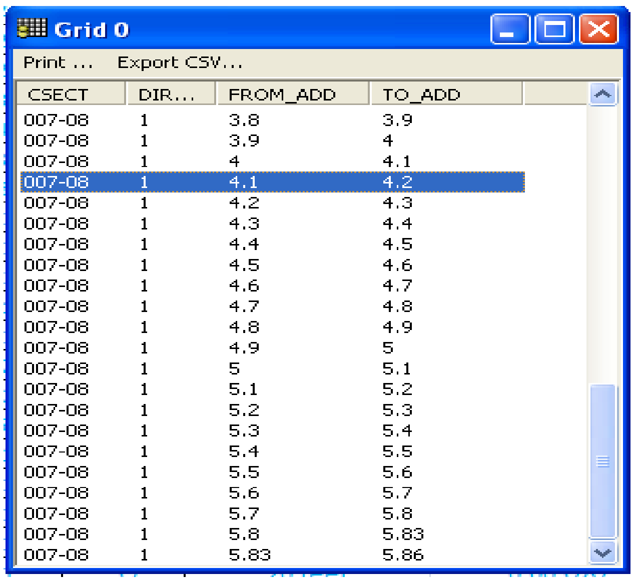



**Figure 14**
**Inputs for a project in district 61 in Visidata**

Log mile limits of the pavement were available in the LADOTD mainframe. Grid '0,' shown in Figure 15, was used to control the log mile limits for the various projects. After identifying the location of the first joint, joint spacing was approximated by calculating the difference between mileages in each frame of the video (this value may be same as the value of the begin log mile). Hence, this calculation provided the exact location of the next joint. The process was repeated continuously until the pavement section reached the end log mile. Every crack at the joints was then counted and added to calculate the RCI based on equation (2).



Grid 0

Print ... Export CSV...

| CSECT | DIR... | FROM_ADD | TO_ADD |
|---|---|---|---|
| 007-08 | 1 | 3.8 | 3.9 |
| 007-08 | 1 | 3.9 | 4 |
| 007-08 | 1 | 4 | 4.1 |
| 007-08 | 1 | 4.1 | 4.2 |
| 007-08 | 1 | 4.2 | 4.3 |
| 007-08 | 1 | 4.3 | 4.4 |
| 007-08 | 1 | 4.4 | 4.5 |
| 007-08 | 1 | 4.5 | 4.6 |
| 007-08 | 1 | 4.6 | 4.7 |
| 007-08 | 1 | 4.7 | 4.8 |
| 007-08 | 1 | 4.8 | 4.9 |
| 007-08 | 1 | 4.9 | 5 |
| 007-08 | 1 | 5 | 5.1 |
| 007-08 | 1 | 5.1 | 5.2 |
| 007-08 | 1 | 5.2 | 5.3 |
| 007-08 | 1 | 5.3 | 5.4 |
| 007-08 | 1 | 5.4 | 5.5 |
| 007-08 | 1 | 5.5 | 5.6 |
| 007-08 | 1 | 5.6 | 5.7 |
| 007-08 | 1 | 5.7 | 5.8 |
| 007-08 | 1 | 5.8 | 5.83 |
| 007-08 | 1 | 5.83 | 5.86 |

**Figure 15**
**Grid showing the log miles in tenth of a mile**

Performance of a given treatment method against reflective cracking was assessed by plotting a graph between RCI and the number of years in service. An RCI graph for a section in which fiber-glass grid was used is presented in Figure 16. Project 258-02-0016 was constructed in 1997 including an untreated segment constructed in the same year. RCI was calculated for the years 2000, 2003, 2005, 2007, and 2009, which were considered as 3, 6, 8, 10 and 12 years from the date of construction, respectively. In some instances, the year of construction for treated and untreated sections was not the same. This eventually presented a difference in “years from construction” between treated and untreated sections. However, this discrepancy was resolved by comparing the treated and untreated sections based on the number of years in service from the date of construction. For sections other than those treated with fiber-glass grid, RCI was calculated for the years 2007 and 2009 only. This situation was encountered after failure of the server, which contained videos for earlier years.

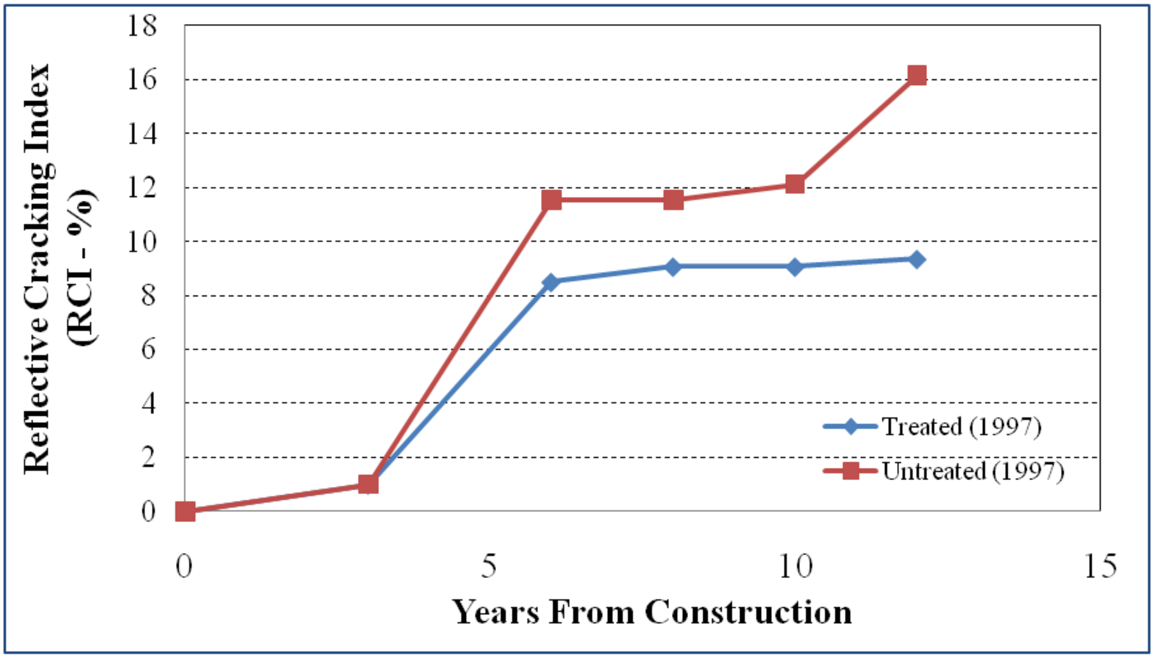



**Figure 16**
**Typical RCI plot for a fiber glass-grid project**

## Pavement Condition Index

This study used the PCI to assess the overall rideability condition of the pavement and its overall performance. The PCI provided a comprehensive tool of the exact time and condition when a rehabilitation or reconstruction program was necessary for a pavement. In Louisiana, the PCI is calculated considering various distresses. Depending on the type of pavement, distress types vary. For flexible pavements and composite pavements, PCI is a function of random cracking index, alligator cracking index, patching index, roughness index, and rutting index. Whereas, for jointed concrete pavement, PCI is a function of a longitudinal cracking index, a transverse cracking index, a patching index, and a roughness index, and continuously reinforced concrete pavement has the same indices; however, a transverse cracking index was not considered. Depending on a roadway classification, such as Interstate, National Highway, or State Highway, etc., various trigger values of PCI are used to identify the rehabilitation or reconstruction conditions of the pavement. Table 6 presents various trigger values and respective PCI limits.

**Table 6**
**Values used to identify the rehabilitation stage**

| CONDITION | INTERSTATES | NHS | RHS & SHS |
|---|---|---|---|
| Very Good | 100-96 | 100-95 | 100-95 |
| Good | 95-90 | 94-88 | 94-85 |
| Fair | 89-76 | 87-70 | 84-65 |
| Poor | 75-65 | 69-60 | 64-50 |
| Very Poor | 64-0 | 59-0 | 49-0 |

NHS: National Highway of Significance
SHS: State Highway of Significance
RHS: Rural Highway of Significance

The following formula is used by the Department to calculate the PCI for composite and flexible road sections:

PCI = MAX (MIN (RNDM, ALCR, PTCH, RUFF, RUT), {AVG (RNDM, ALCR, PTCH, RUFF, RUT) – 0.85 STD (RNDM, ALCR, PTCH, RUFF, RUT}) (3)

The following formula is used to calculate the PCI for JPCP sections:

PCI = MAX (MIN (LONG, TRAN, PTCH, RUFF), {AVG (LONG, TRAN, PTCH, RUFF) – 0.85 STD (LONG, TRAN, PTCH, RUFF)}) (4)

The following formula is used to calculate the PCI for CRCP sections:

PCI = MAX (MIN (LONG, PTCH, RUFF), {AVG (LONG, PTCH, RUFF) – 0.85 STD (LONG, PTCH, RUFF)}) (5)

where,
RNDM = random cracking index;
ALCR = alligator cracking index;
PTCH = patch index;
RUFF = roughness index;
RUT = rutting index;
LONG = longitudinal index
TRAN = transverse index; and
STD = standard deviation.

After collecting the basic information of a project, district and parish information was used to identify the project numbers in the LADOTD PMS database. Using log mile limits, the values of PCI were determined for every project. The PCI, similar to other indices, is expressed in percentage on a scale ranging from 0 to 100. Since the trigger values and index values hold compatible units, there was no need to use models for conversion.

**Predicted Average Service Lives**

The predicted average service life of a pavement was the most important factor in the performance analysis. The service life of a pavement was predicted by means of a second degree polynomial model, as shown in Figure 17. The fitted model predicted the average service life using the trigger values shown in Table 6. The PCI was obtained from the Intranet Web site using the index plots for each year. These values were then plotted against the number of years from the date of construction. A second degree polynomial trend line was determined in Microsoft Excel. The trigger value was set in the polynomial equation as the value of “y”; then the value of “x” was calculated.

Various trigger values were used depending on the functional classification of the roadway, see Table 6. Poor condition was considered to be the rehabilitation trigger point for all road types. The value of “x” was the year at which pavement performance falls below the trigger value. That particular value of “x” was considered to be the service life of the pavement. A similar procedure was followed for all pavement sections for both treated and untreated segments. This analysis used the estimated service life values to establish a performance comparison analysis between treated and untreated sections. The difference between the predicted service life of the treated section and the respective untreated section was calculated. If the difference was positive, the treatment is expected to result in a positive effect in performance for that particular pavement section. In order to identify a conclusive trend for each treatment in terms of performance, a sufficient number of projects were analyzed under each category. However, only a few numbers of projects were available to satisfy the selection requirements for a detailed analysis in the STRATA®, SAMI, and paving fabrics categories.

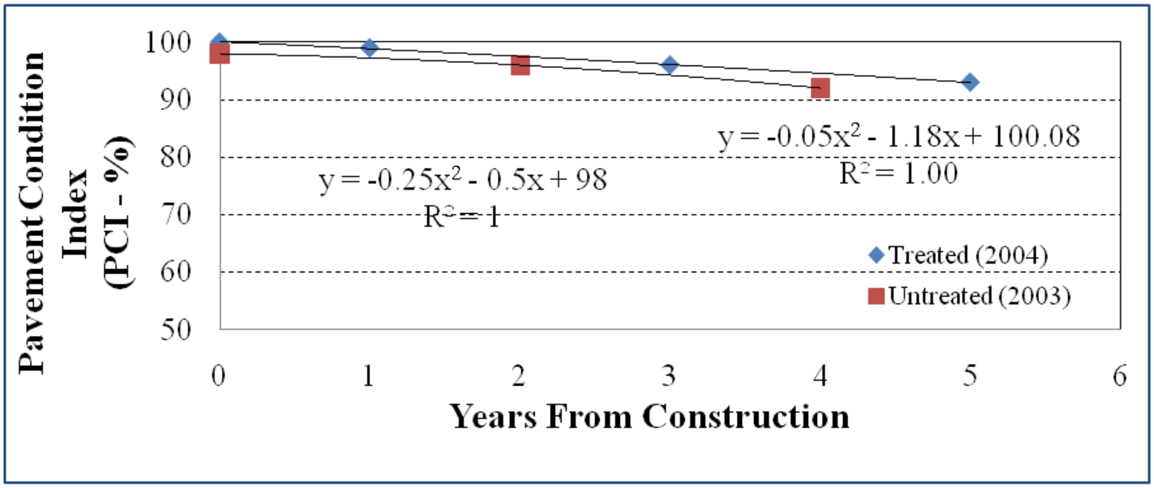



**Figure 17**
**Typical variation of the pavement condition index during the monitored period**

**Economic Analysis**

A simplified economic evaluation was performed on all the projects that were selected for detailed analysis. The adopted approach avoided to make unnecessary assumptions with respect to future rehabilitation strategies and user costs over an extended analysis period. In this approach, the performance service life of each selected site was determined in order for the PCI to drop to a terminal threshold ($PCI_T$ = 64, 69, or 75 depending on the road classification as presented in Table 6). The total cost of the rehabilitation strategy, obtained from bid items, was then divided by the performance service life in years and the length of the section. This process determined the annual cost of the treatment per mile, based on the following equation:

$$TAC = \frac{\text{Rehabilitation Cost}}{N * \text{Length}} \tag{6}$$

where,
TAC = total annual cost per mile;
Rehabilitation Cost = total cost of the treatment method, and
N = performance service life in years.

By comparing the TAC of the treated segment to the TAC of the untreated segment, one may determine the cost effectiveness of the treatment method. The limitations of this approach are as follows: (a) it does not consider routine maintenance activities such as crack sealant during the overlay service life, and (b) it assumes that user costs are the same for both treated and untreated segments. These assumptions were deemed acceptable for the state of Louisiana in which crack sealant is rarely used. Total construction cost, including the cost of the overlay (both binder course and wearing course, depending upon the design) and cost of treatment, were considered for the treated sections. For the untreated sections, the cost of the overlay (both binder course and wearing course, depending upon the design) was the sole construction cost. The analysis assumed that the cost of rehabilitation would be same for the untreated and treated sections. If the total annual cost of the treated segment is less than that of the untreated section, then that treatment was considered to be cost-effective. While this analysis showed a positive improvement for some of the treated sections, others showed a negative influence. Therefore, the overall trend was considered in assessing the cost-effectiveness of the individual treatment strategy.

**Extraction of Cost Data.** Cost data included the cost of the crack control treatment method, as well as the cost of overlay. This study extracted data from two sources: the Mainframe database and the Intranet Web site of the LADOTD. In some cases, the year of construction for the untreated section dated back to the 1980s and the cost data were unavailable. In this case, the cost of overlay per mile for the untreated sections was assumed to be same as that of the treated sections. Inflation factors were taken from the U.S. Bureau of Labor Statistics, available online through the following link: http://data.bls.gov/cgi-bin/cpicalc.pl *[77]*. For each project, the costs of construction were shifted to the most recent year of construction for the treated and untreated sections.

On average, the cost of HMA per ton was $42. The average cost of fiber-glass grid per square yard was $6.35; the average cost of chip seal per square yard was $2; the average cost of saw and seal of joints per linear foot was $1.60; the average cost of SAMI per square yard was $1.70; the average cost of paving fabric per square yard was $2.30; the average cost of STRATA® per square yard was $7.60.

## Theoretical Investigation

The mechanism in which the saw and seal method is contributing to rehabilitated pavements was investigated using a two-dimensional (2D) finite element (FE) approach. Figure 18 presents the general layout of the FE model; in total, 7,168 elements were used to simulate the pavement structure. The horizontal dimension of the modeled portion was 89 in. The FE model simulated an HMA overlay with a thickness of 3 in. on top of a 10-in. concrete layer. The criticality of the stress field associated with the opening (Mode I) and shearing (Mode II) modes of loading was simulated by considering a jointed concrete layer, which is subjected to thermal horizontal movement and to traffic loading. Thermal movement was simulated by imposing a horizontal slab movement of 0.004 in/sec on the concrete layer. A single tire applying a load of 8992 lb. on the pavement structure over an equivalent rectangular area was simulated with a uniform pressure of 105 psi.

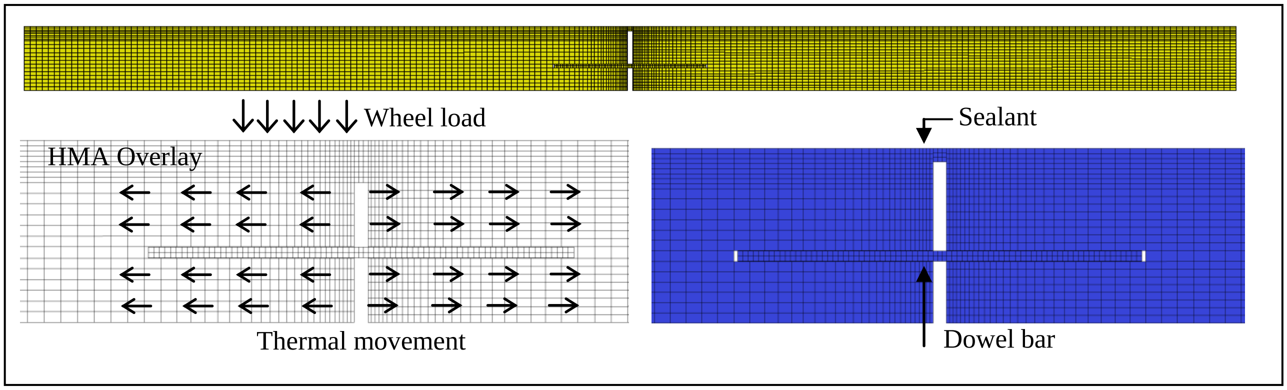



**Figure 18**
**General layout of FE model**

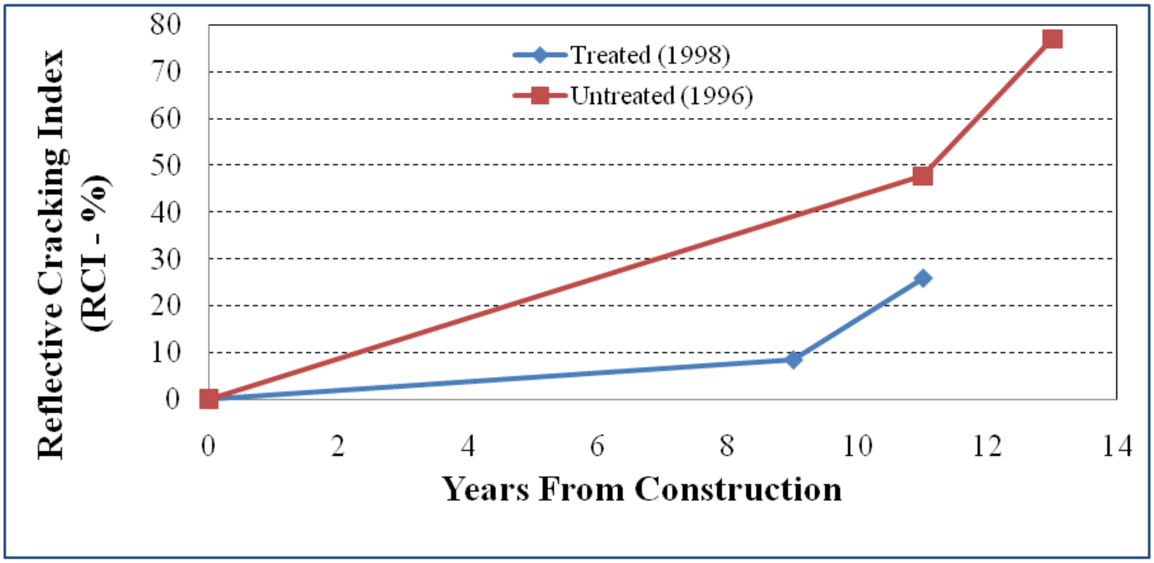
To investigate the effectiveness of the saw and seal method, two models were simulated: one incorporating the saw and seal method in the construction of the overlay, and the other with a control with the overlay applied directly to the concrete layer. While the sealant material, concrete layer, and dowel bar were assumed to respond elastically to the load ($E_{sealant}$ = 3 ksi, $E_{concrete}$ = 4000 ksi, $E_{steel}$ = 29000 ksi), the HMA overlay was simulated as a viscoelastic material using a generalized Kelvin model *[78]*. The viscoelastic model consists of a spring and n-Kelvin elements connected in series with the following Prony series coefficients: $\tau_i$ = 0.001, 0.01, 0.1, 1, 10, 100, 1000, 10000, 1 x $10^5$, 1 x $10^6$, 1 x $10^7$ and $g_i$ = 0.791, 0.676, 0.526, 0.356, 0.2, 0.0912, 0.0349, 0.0123, 0.00465, 0.00207, and 0.00114, where τi's are the relaxation times and $g_i$'s are material constants referred to as relaxation strengths. As part of the viscoelastic definition of HMA, the initial instantaneous modulus was assumed to be 500 ksi in order to define the elastic component of HMA.

# DISCUSSION OF RESULTS

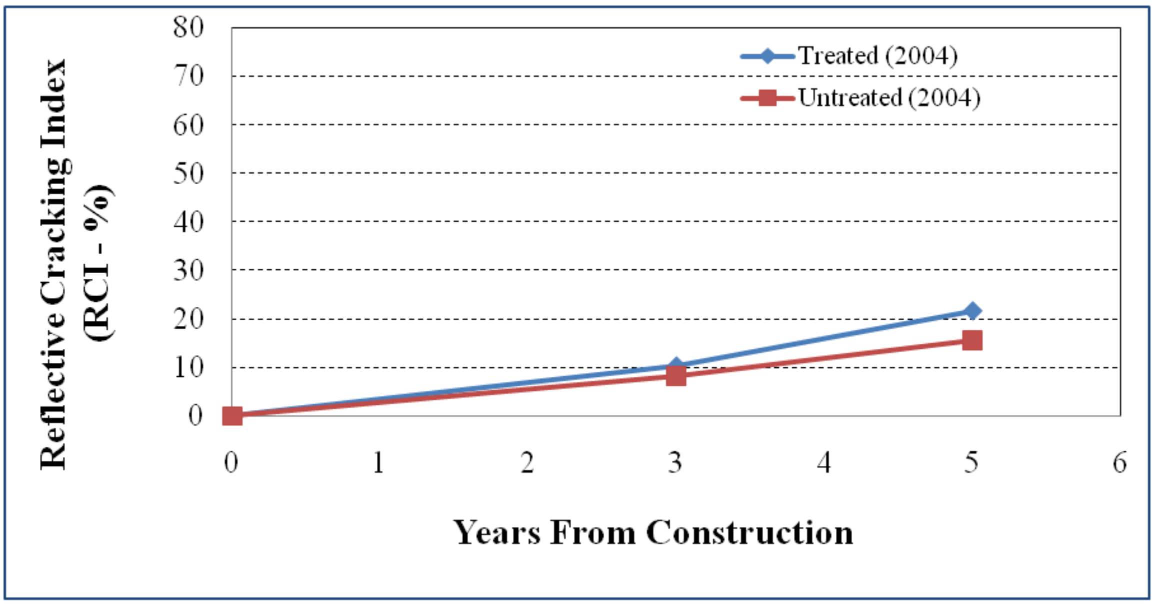
Results presented in this section are divided into performance and cost-effectiveness evaluations for each treatment method. The performance of the different treatment methods were assessed by evaluating performance data obtained from the LADOTD pavement management system for the period ranging from 1995 to 2009. The RCI and PCI were the two parameters used to assess the performance of the pavement sections. A simplified economic evaluation was then performed for each treatment method to assess its cost-effectiveness. Since mixed trends were observed by considering the performance of the individual projects, the overall trend was considered in assessing the cost-effectiveness of each treatment method.

## Reflective Cracking Index

RCI graphs were created for all selected projects in which treatments were used, except for saw and seal. In saw and seal projects, sealed cracks were surveyed to identify double cracking. As previously mentioned, projects with fiber-glass grid had data from the year 2000, while the rest of the projects contained data for years 2007 and 2009 only. RCI calculated and assessed pavement performance against reflective cracking, while PCI predicted the average service life. Examples of RCI trends for different treatment methods are presented in Figures 19 to 23. Figure 19 (a) and (b) presents two projects in which chip seal was applied as an interlayer treatment. Figure 19 (a) presents a site in which the application of chip seal as an interlayer improved the performance against reflective cracking. In contrast, Figure 19 (b) demonstrates that the RCI was higher in the treated section than in the untreated section. Similarly, Figure 20 (a) and (b) presents two sites in which a fiber-glass grid was used; in one of the sites, the performance of the treated section was comparable to the performance of the untreated section, while the other site showed that the RCI was higher in the treated section than in the untreated section. Similarly, Figures 21, 22, and 23 represent sites in which SAMI (Stress Absorbing Membrane Interlayer), paving fabrics, and STRATA® were used. In general, results of the RCI were mixed for the different treatment methods; therefore, these results were not used to draw conclusions as to the effectiveness of each treatment method.



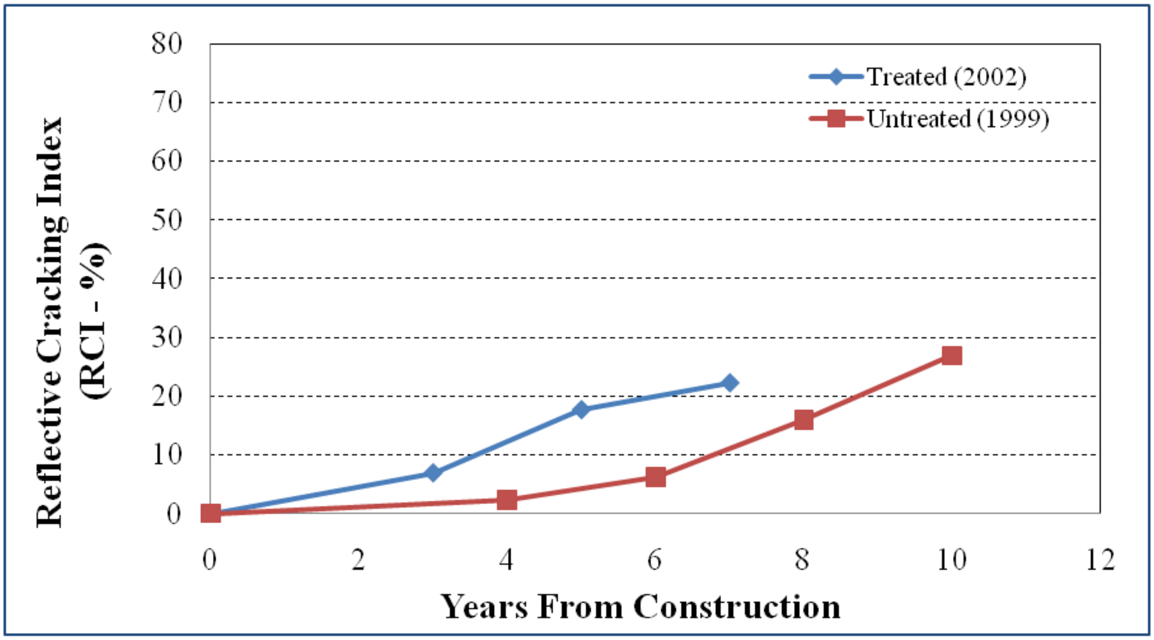

(a) Chip Seal




(b) Chip Seal

**Figure 19**
**RCI plots for selected projects in chip seal category**


**(a) Fiber-glass grid**




**(b) Fiber-glass grid**

**Figure 20**
**RCI plots for selected projects in fiber-glass grid category**

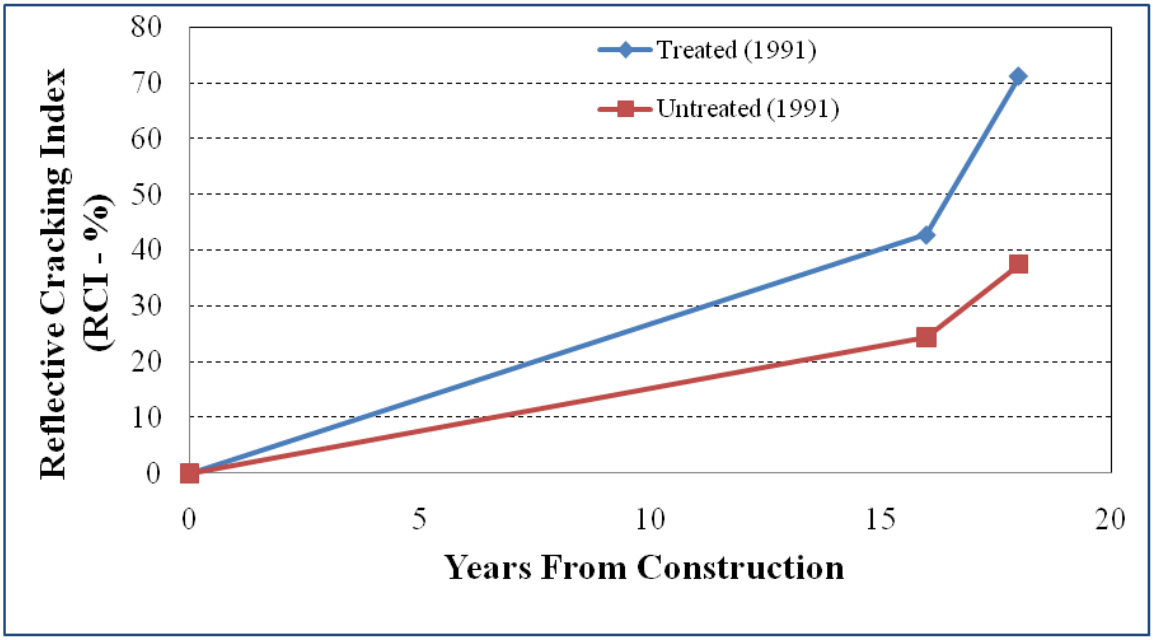



**Figure 21**
**RCI plot for a SAMI project**

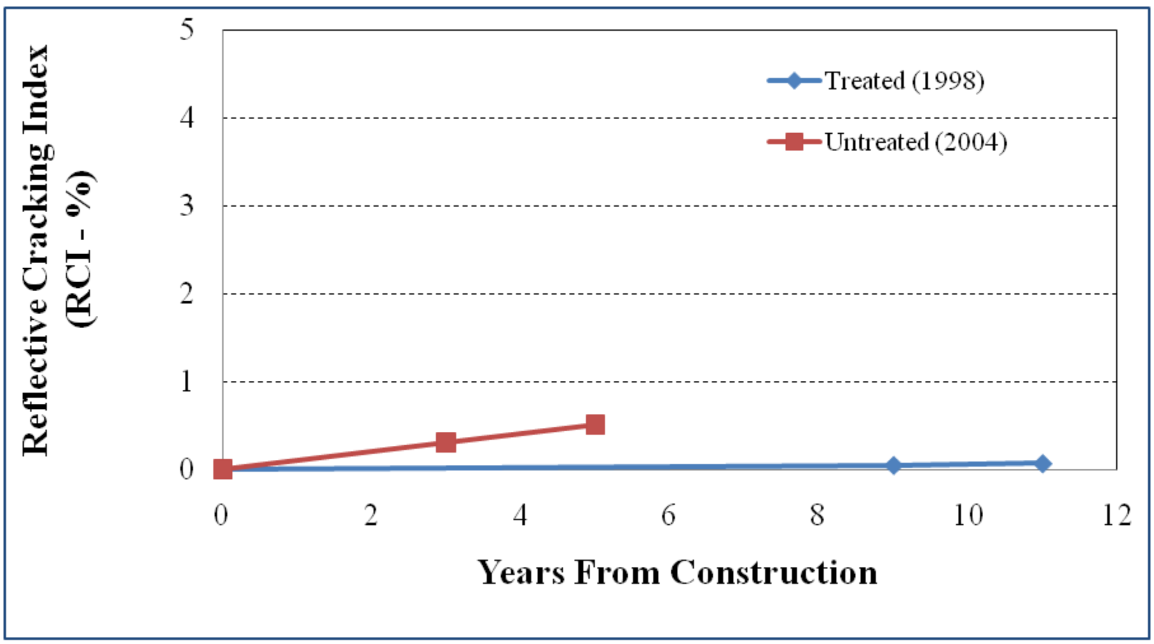



**Figure 22**
**RCI plot for a paving fabric project**


**Figure 23**
**RCI plot for a STRATA® project**

The RCI values at the end of the monitoring period (2009) for all sites are presented in Table 7. The RCI values for the untreated sections of Projects 016-05-0028 and 001-08-0035 were not calculated. These projects were rehabilitated multiple times after original construction. This process caused an increase and a decrease trend in the RCI. However, in the case of service life prediction, the earliest year from construction where the performance fell below the trigger value, was considered as the service life.

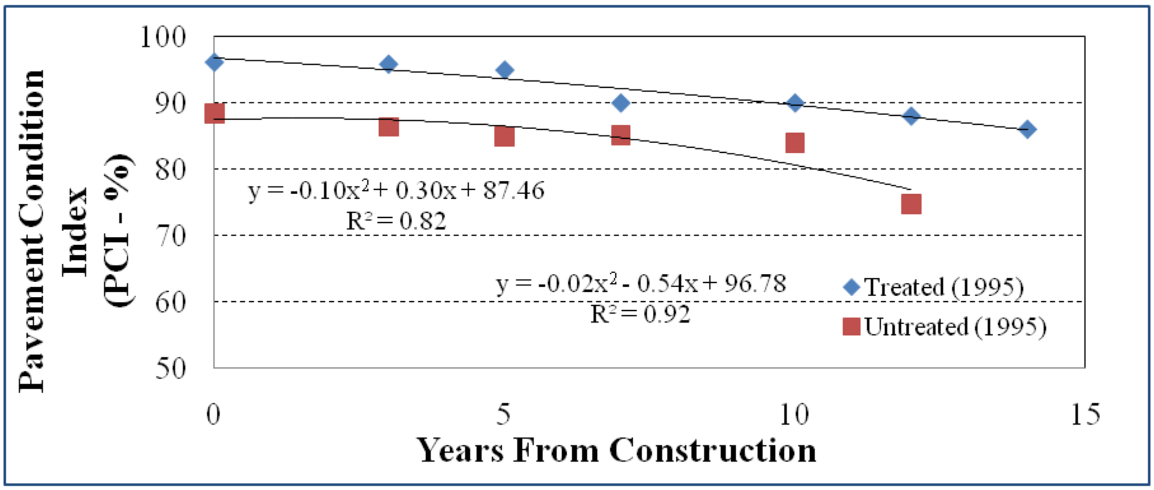
The values in Table 7 provide a comparison of the reflective cracking performance for projects with and without treatment. For example, Project 410-01-0029 showed 26.5 percent RCI after 10 years from construction, while the respective untreated section showed 27.3 percent RCI after 19 years from construction. Project 261-04-0021 was evaluated for both STRATA® and chip seal. The log mile limits were 2.2 to 4.6 and 4.6 to 6.6, respectively, for these treatments. As previously noted, results of the RCI were mixed for the different treatment methods and, therefore, these results were not used to draw conclusions as to the effectiveness of each treatment method.

**Table 7**
**RCI values at the end of monitoring period (2009)**

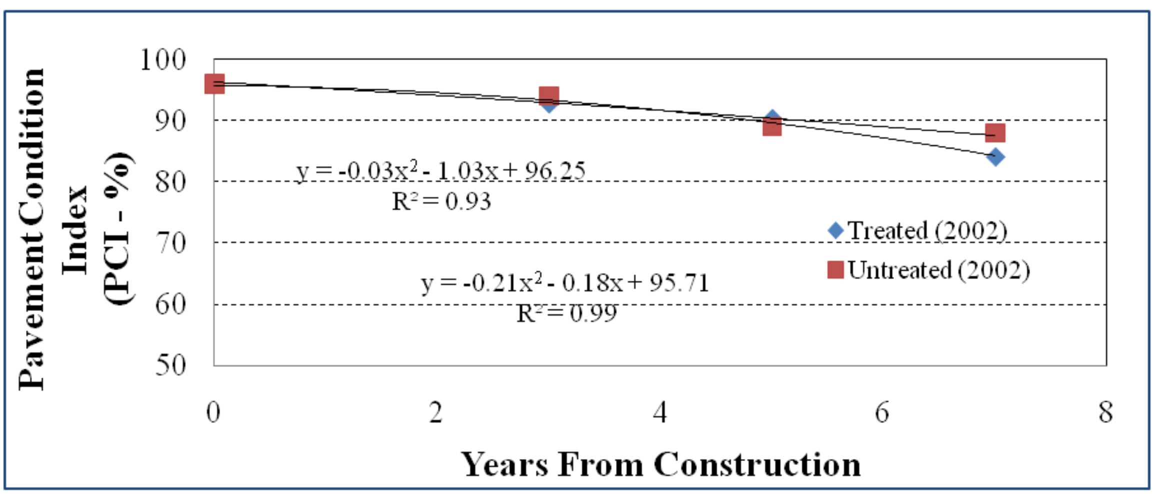
| Project | Treatment | Date of Construction | | Years in Service | | RCI | |
|---|---|---|---|---|---|---|---|
| | | Treated | Untreated | (T) | (U) | (T) | (U) |
| **410-01-0029** | Fiber-glass grid | Jan-99 | Jun-90 | 10 | 19 | 26.5 | 27.3 |
| **056-03-0025** | Fiber-glass grid | Oct-96 | Aug-81 | 13 | 28 | 33.2 | 95.3 |
| **025-08-0054** | Fiber-glass grid | Oct-03 | Apr-93 | 6 | 16 | 10.9 | 55.3 |
| **007-08-0030** | Fiber-glass grid | Jan-05 | Aug-97 | 4 | 12 | 0.2 | 44.7 |
| **013-04-0036** | Fiber-glass grid | Mar-00 | Mar-92 | 9 | 17 | 20.4 | 28.4 |
| **019-01-0031** | Fiber-glass grid | Oct-02 | Apr-99 | 7 | 10 | 22.2 | 26.9 |
| **008-02-0029** | Fiber-glass grid | Nov-03 | Oct-00 | 6 | 9 | 11.5 | 22.3 |
| **052-01-0017** | Fiber-glass grid | Nov-04 | Oct-86 | 5 | 18 (5) | 11.5 | 3.0 |
| **052-03-0026** | Fiber-glass grid | Oct-02 | Jul-88 | 7 | 14 (7) | 6.6 | 10.2 |
| **017-04-0043** | Fiber-glass grid | Aug-00 | Sep-96 | 9 | 13 | 11.2 | 50.0 |
| **013-09-0035** | Fiber-glass grid | Jan-95 | Dec-95 | 14 | 14 | 53.0 | 57.6 |
| **258-02-0016** | Fiber-glass grid | Jun-97 | Jun-97 | 12 | 12 | 9.4 | 16.2 |
| **008-08-0028** | Fiber-glass grid | Jan-03 | Jun-00 | 6 | 9 | 5.7 | 51.9 |
| **055-04-0017** | Chip seal | Oct-03 | Mar-89 | 6 | 20 | 48.8 | 73.6 |
| **002-03-0039** | Chip seal | Oct-04 | Feb-03 | 5 | 6 | 4.0 | 7.7 |
| **016-05-0028** | Chip seal | Oct-04 | Jul-79 | 5 | 21 | 14.8 | N/A |
| **020-08-0025** | Chip seal | May-04 | Nov-03 | 5 | 6 | 9.0 | 4.9 |
| **067-08-0014** | Chip seal | Nov-03 | Dec-99 | 6 | 10 | 2.5 | 0.8 |
| **023-05-0039** | Chip seal | Nov-04 | Jul-02 | 5 | 7 | 0.6 | 12.8 |
| **015-03-0023** | Chip seal | Sep-04 | Aug-95 | 4 | 14 | 3.5 | 5.1 |
| **261-04-0021** | Chip seal | Dec-04 | Jun-96 | 4 | 13 | 21.9 | 77.0 |
| **261-04-0019** | Chip seal | Sep-98 | Jun-96 | 11 | 13 | 25.9 | 77.0 |
| **058-01-0024** | Chip seal | Mar-05 | Sep-98 | 4 | 11 | 11.6 | 53.6 |
| **047-01-0040** | Chip seal | Oct-03 | Sep-94 | 6 | 15 | 41.7 | 73.7 |
| **279-04-0022** | Chip seal | Nov-04 | Nov-04 | 5 | 5 | 21.7 | 15.6 |
| **413-30-0010** | SAMI | Feb-92 | Jul-96 | 17 | 13 | 41.8 | 31.1 |
| **020-09-0025** | SAMI | Mar-91 | Aug-91 | 18 | 18 | 71.2 | 37.5 |
| **019-05-0024** | SAMI | Oct-93 | Sep-03 | 16 | 6 | 0.3 | 2.7 |
| **067-09-0038** | Paving Fabric | Apr-01 | Dec-99 | 8 | 10 | 4.9 | 0.8 |
| **451-07-0051** | Paving Fabric | Nov-03 | Dec-04 | 6 | 5 | 0.1 | 0.5 |
| **451-05-0086** | Paving Fabric | Apr-98 | Dec-04 | 11 | 5 | 0.1 | 0.5 |
| **451-08-0060** | STRATA® | Nov-03 | Dec-04 | 6 | 5 | 0.2 | 0.5 |
| **261-04-0021** | STRATA® | Dec-04 | Jun-96 | 5 | 13 | 1.0 | 77.0 |
| **001-08-0035** | STRATA® | Mar-04 | Nov-80 | 5 | 15 | 22.6 | N/A |

## Pavement Condition Index

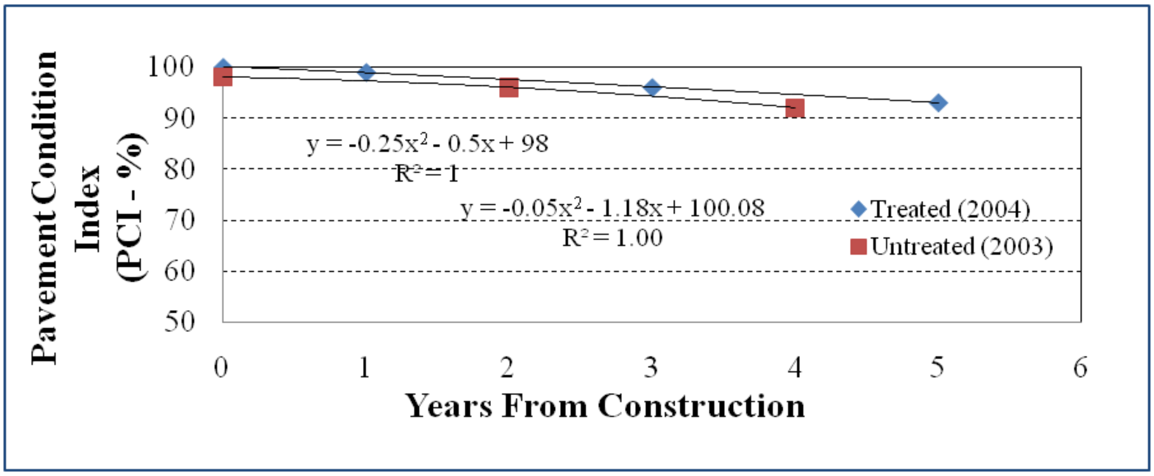
Figure 24 shows PCI trends for a number of sections illustrating the different treatment categories. Figure 24 (a) and (b) presents PCI plots for two of the sites, which were sawed and sealed; similarly, Figure 24 (c) and (d) presents plots for sites treated with chip seal. Figure 24 (e) and (f) presents plots for sites treated with fiber-glass grid; Figure 24 (g) and (h) represents plots for sites treated with SAMI; Figure 24 (i) presents a plot for sites treated with paving fabrics; and Figure 24 (j) presents a plot for sites treated with STRATA®. Similar graphs were plotted for all the projects selected for detailed analysis.



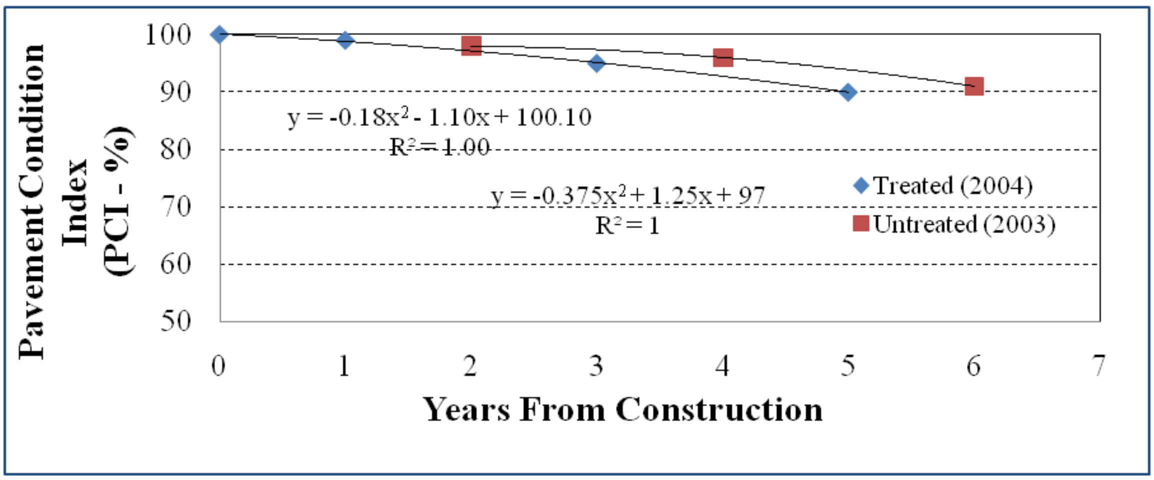

**(a) Saw and Seal**



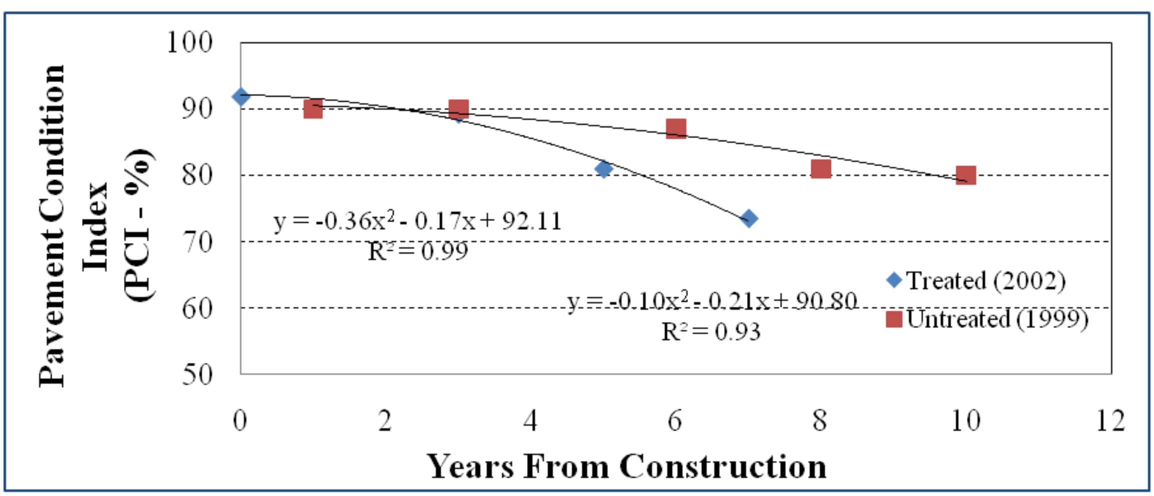

**(b) Saw and Seal**



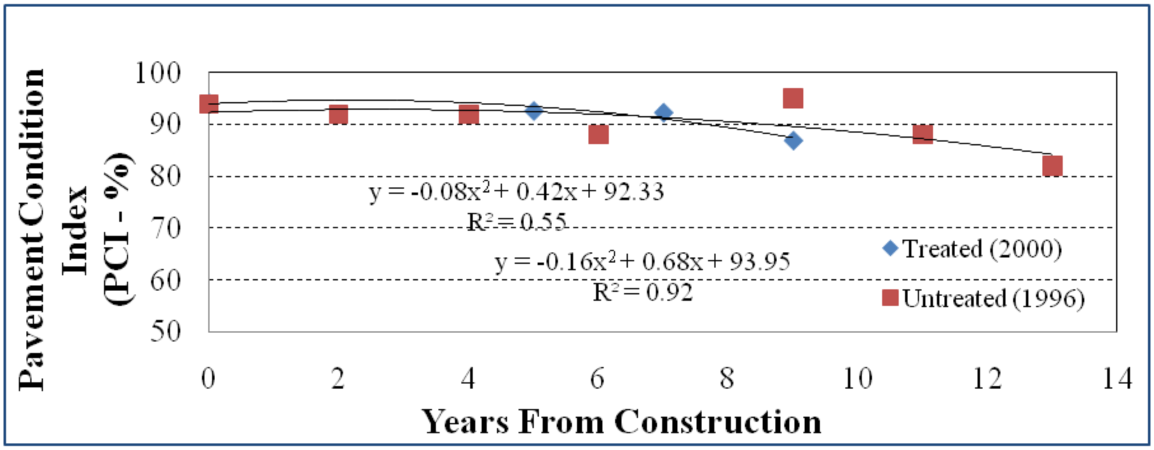

**(c) Chip Seal**



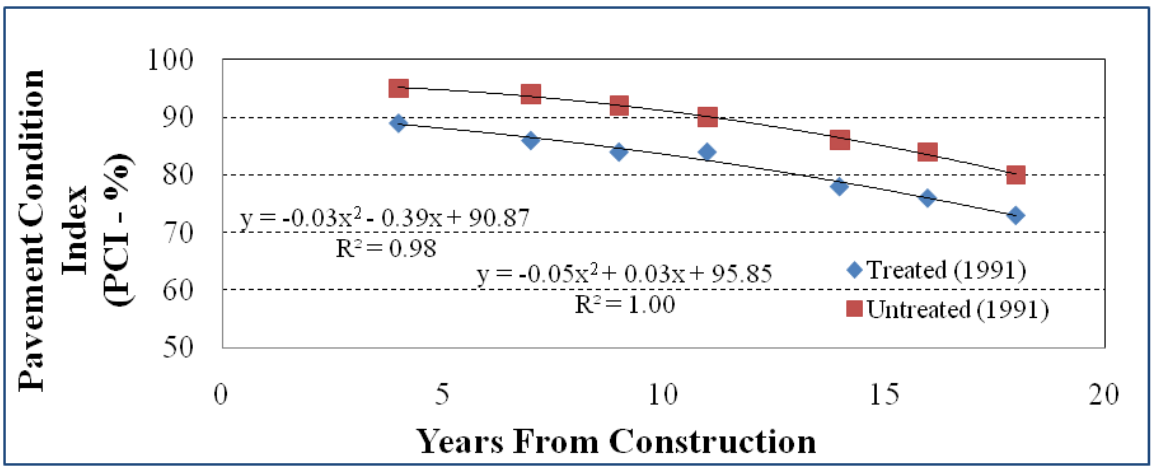

**(d) Chip Seal**



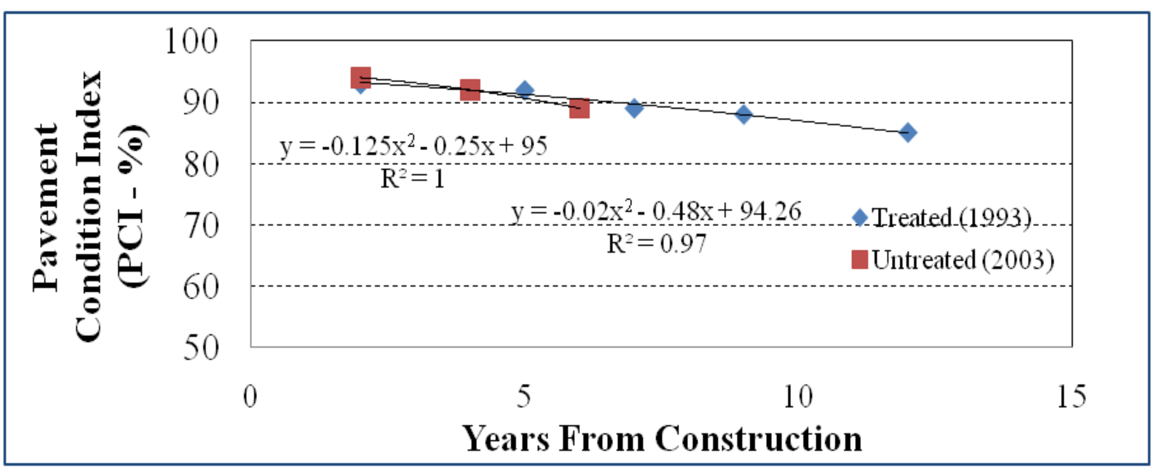

**(e) Fiber-glass grid**



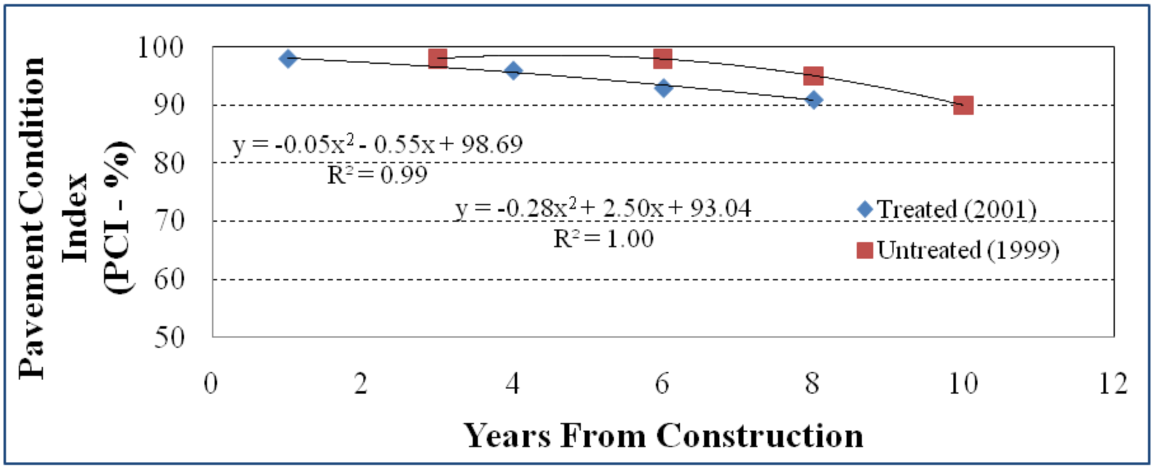

**(f) Fiber-glass grid**



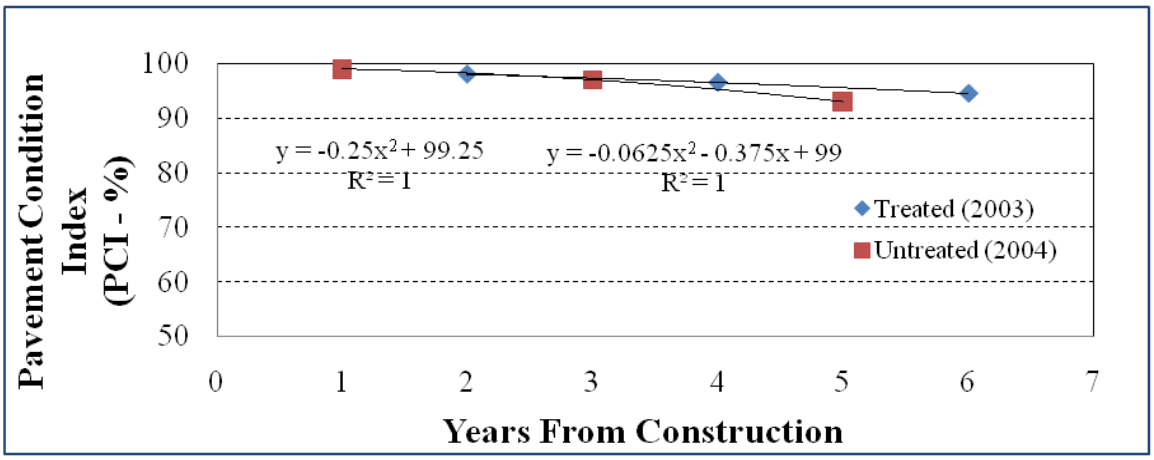

**(g) SAMI**




**(h) SAMI**




**(i) Paving Fabric**




**(j) STRATA®**

**Figure 24**
**PCI plots for selected projects in different treatment categories**

## Predicted Service Lives

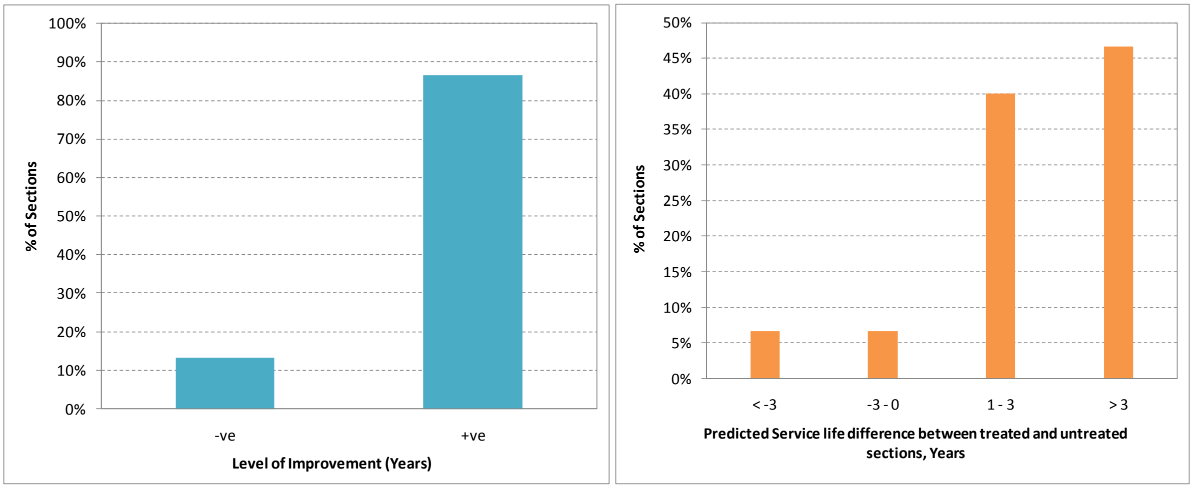
The service lives of the pavement sections were estimated using the plots created (PCI vs. years from construction) rounding off the value of the predicted service life to the lower year value. Direct comparisons between the predicted service lives of treated sections were made with those of untreated sections. Predicted service lives, levels of improvement, and/or negative impacts of various treatment methods for different categories of treatment are discussed in the following sections.

### Saw and Seal

Using the aforementioned analysis approach, this study calculated the service lives of the saw and seal sections until the terminal pavement condition index would be reached. Table 8 illustrates the predicted service lives for the treated and untreated sections. In order to identify the general trends in the tabulated results, Figure 25 categorizes the level of improvement or disimprovement due to saw and seal into a structured histogram. In this figure, individual sites are grouped into classes that exhibit similar levels of contribution from the saw and seal. As shown by these results, 87 percent of the sites showed a positive improvement ranging from 1 to 12 years, while the remaining 13 percent of the sites showed a negative contribution as a result of the treatment. About 40 percent of the sections showed an improvement from 1 to 3 years, while 47 percent of the evaluated sections showed an improvement from 4 to 12 years. The average level of improvement due to saw and seal was found to be 4 years.

**Table 8**
**Predicted average service lives (saw and seal)**

| Site ID | Project Number (Treated) | Predicted Service Life | | Trigger Value |
|---|---|---|---|---|
| | | Treated Section | Untreated Section | |
| 1 | 065-04-0034 | 15 | 8 | 64 |
| 2 | 004-01-0036 | 13 | 8 | 69 |
| 3 | 012-11-0034 | 15 | 12 | 69 |
| 4 | 012-13-0088 | 19 | 18 | 69 |
| 5 | 451-04-0030 | 20 | 10 | 75 |
| 6 | 054-05-0017 | 10 | 17 | 64 |
| 7 | 008-07-0028 | 26 | 15 | 69 |
| 8 | 008-09-0052 | 23 | 11 | 69 |
| 9 | 015-01-0046 | 20 | 17 | 69 |
| 10 | 023-01-0043 | 18 | 13 | 69 |
| 11 | 033-01-0027 | 18 | 14 | 64 |
| 12 | 035-02-0021 | 13 | 11 | 64 |
| 13 | 414-01-0021 | 18 | 20 | 64 |
| 14 | 450-08-0037 | 13 | 11 | 75 |
| 15 | 454-02-0026 | 18 | 16 | 75 |

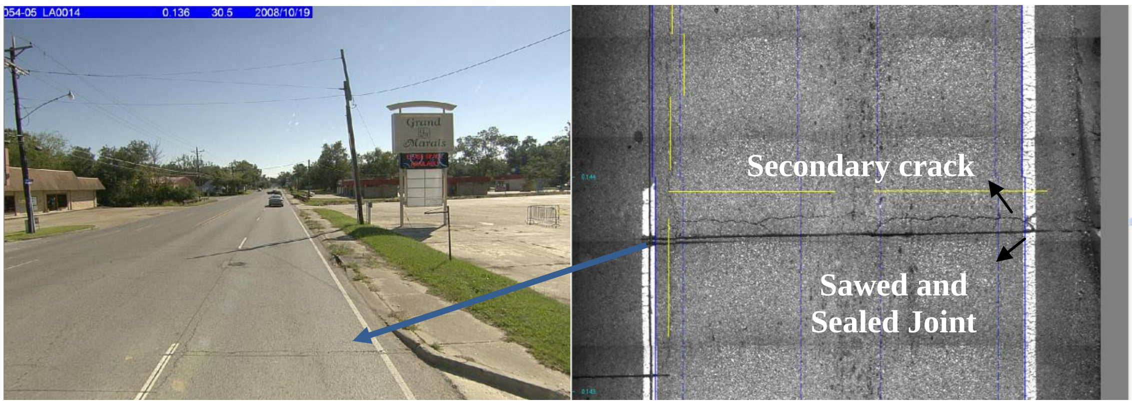



(a) (b)

**Figure 25**
**Contribution of saw and seal to the predicted pavement service lives**

**Secondary Cracking.** The success of saw and seal operations mainly depends on applying the treatment at the exact locations of the joints. Past research studies reported that a saw cut more than 1 in. from the joint would result in secondary cracking *[63]*. The percentage of secondary cracks was determined by examining the cracking pattern in the video crack surveys at each joint location, Figure 26 (a) and (b). If a second crack appeared close to the sawed and sealed joint, it was considered to be a double crack. This may happen if the overlay is not properly sawed and sealed at the exact joint location. This analysis revealed that the percentage of secondary cracks in those sites where saw and seal did not perform well or similar to the untreated sections was 0.6 percent. On the other hand, the average percentage of secondary cracks in those sites where saw and seal outperformed the untreated sections was 0.5 percent. This low level of secondary cracks in the evaluated sites indicates that the approach adopted in Louisiana to locate the joints after placement of the overlay is effective in minimizing secondary cracks.

**Traffic Analysis.** The effectiveness of saw and seal on various traffic levels was investigated. Figure 27 categorizes the average level of improvements in the pavement service life, depicted in Table 8 for three levels of traffic. These three traffic levels consist of low (AADT less than 7,000); medium (AADT from 7,000 to 14,000); and high (AADT greater than 14,000). These definitive levels of traffic are based on LADOTD specifications. As shown in this figure, it appears that saw and seal is more effective for low and medium traffic levels compared to high traffic levels. In fact, the two sites in which the untreated sections outperformed the treated sections are in the high traffic category. One possible reason for this trend is that the increase in traffic loading may result in minor rutting in the wheel paths, which may cause the sealant to come off with time and, therefore, gradually decrease the serviceability of the pavement structure. While the analysis showed that this treatment method was more effective in sections with low to medium traffic volumes, contact with project engineers across the state indicated that the performance of this treatment was similar for low, medium, and high traffic volumes. Therefore, additional analysis is needed to determine the exact influence of traffic volumes on saw and seal.




**(a)**


**(b)**

**Figure 26**
**(a) Dislocated joints and double cracking, (b) sealant condition under high traffic loading**

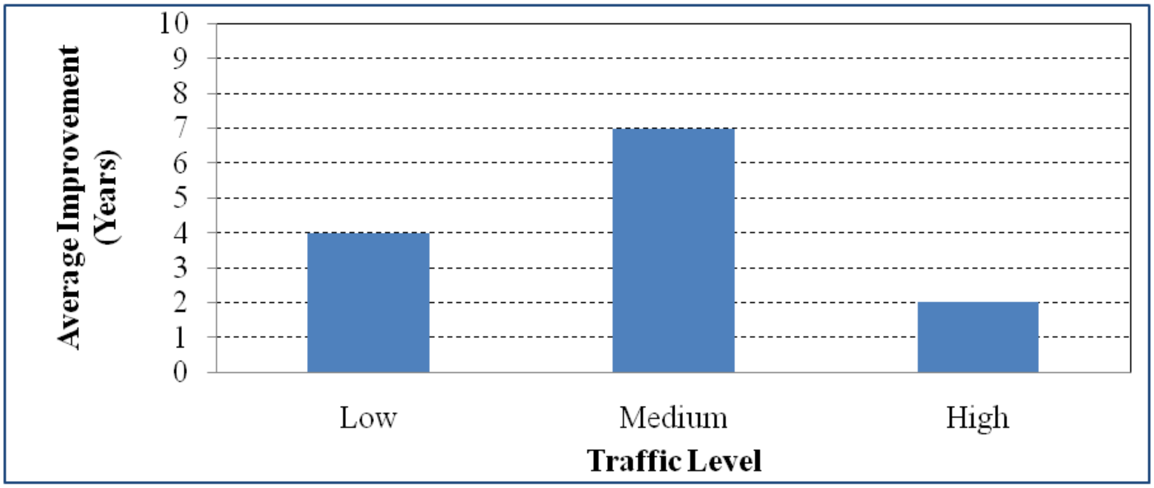
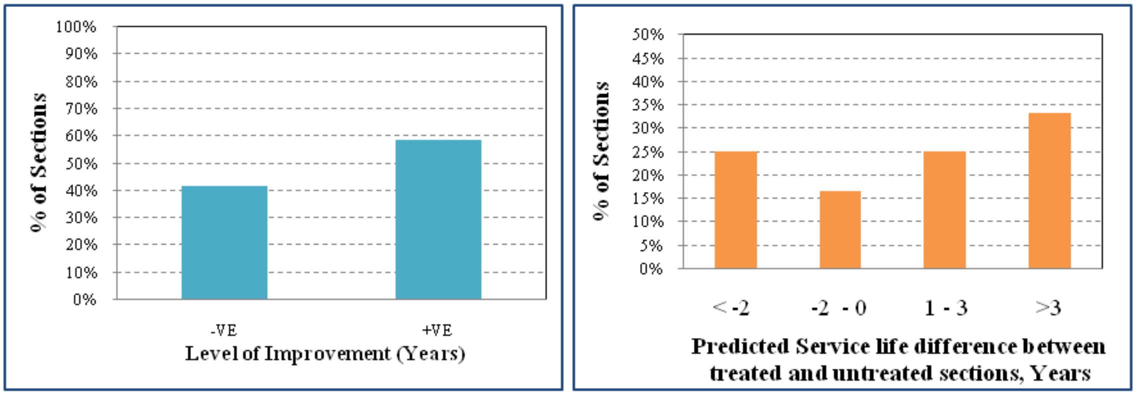



**Figure 27**
**Effects of traffic levels on performance of saw and seal**

### Chip Seal

Twelve different pavement sections were analyzed in which chip seal was used as a treatment for reflective cracking relief. The project locations were presented in Figure 11. Table 9 illustrates the predicted service lives for the treated and untreated sections. In order to identify the general trends in the tabulated results, Figure 28 groups the different projects into classes exhibiting similar levels of contribution from chip seal. It is noted that two sites showed similar performance levels when compared to their respective untreated segments. These sites were considered in the negative category since there was no improvement in service life. As shown by these results, 58 percent of the sites showed a positive improvement ranging from 2 to 10 years, while the remaining 42 percent of the sites showed a negative contribution, i.e., no improvement due to the treatment. Twenty-five percent of the sections showed an improvement from 1 to 3 years and 33 percent of the evaluated sections showed an improvement ranging from 4 to 10 years. Two of the sites showed neither improvement nor disimprovement due to the application of chip seal as a reflective crack relief interlayer. The average level of improvement to the pavement service life was about 2 years.




**(a)** **(b)**

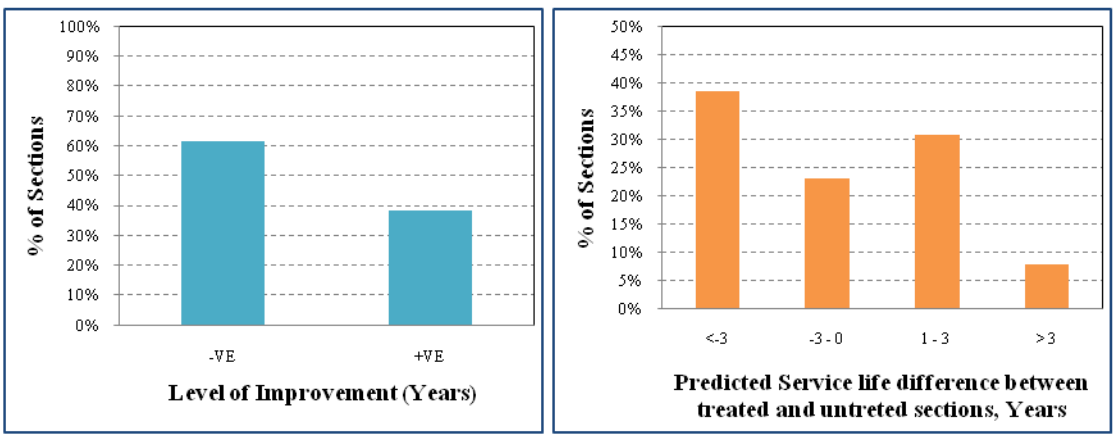
**Figure 28**
**Contribution of chip seal to the predicted pavement service lives**

**Table 9**
**Predicted average service lives (chip seal)**

| Site ID | Project Number (Treated) | Predicted Service Life | | Trigger Value |
|---|---|---|---|---|
| | | Treated Section | Untreated Section | |
| **1** | 055-04-0017 | 14 | 12 | 64 |
| **2** | 002-03-0039 | 16 | 9 | 69 |
| **3** | 016-05-0028 | 20 | 23 | 65 |
| **4** | 020-08-0025 | 10 | 10 | 69 |
| **5** | 023-05-0039 | 18 | 12 | 69 |
| **6** | 261-04-0021 | 14 | 14 | 64 |
| **7** | 261-04-0019 | 24 | 14 | 64 |
| **8** | 058-01-0024 | 17 | 14 | 64 |
| **9** | 047-01-0040 | 10 | 17 | 64 |
| **10** | 279-04-0022 | 16 | 12 | 64 |
| **11** | 067-08-0014 | 11 | 14 | 64 |
| **12** | 015-03-0023 | 12 | 10 | 69 |

### Fiber-Glass Grid

Fiber-glass grid, technically known in Louisiana as roadway reinforcing mesh, may be placed as either a complete road system (area application) or at particular locations in the pavement (strip application). This analysis considered pavement sections in which fiber-glass grid was used as a complete road system. The fiber-glass grid category analyzed a total of 13 projects. Table 10 illustrates the predicted service lives for the treated and untreated sections. In order to identify the general trend in the tabulated results, Figure 29 categorizes the level of improvement or disimprovement due to the use of fiber-glass grid by means of a structured histogram. It is noted that one site displayed a similar performance level when compared to its untreated segment. This was considered as part of the negative impact category since there was no improvement in the service life. In this figure, individual sites were grouped into classes that exhibited similar levels of contribution from fiber-glass grid. As these results showed, 62 percent of the sites reflect a negative impact in which the untreated sections outperformed the treated sections by a range of 0 to 7 years, while the remaining 38 percent of the sites showed a positive contribution ranging from 1 to 6 years. One site showed neither improvement nor disimprovement due to the use of the roadway reinforcing mesh and was considered as part of the negative impact category.



(a) (b)

**Figure 29**
**Contribution of fiber-glass grid to predicted pavement service lives**

**Table 10**
**Predicted average service lives (fiber-glass grid)**

| Site ID | Project Number (Treated) | Predicted Service Life | | Trigger Value |
|---|---|---|---|---|
| | | Treated Section | Untreated Section | |
| **1** | 410-01-0029 | 13 | 17 | 64 |
| **2** | 056-03-0025 | 15 | 13 | 64 |
| **3** | 025-08-0054 | 14 | 16 | 69 |
| **4** | 007-08-0030 | 11 | 11 | 69 |
| **5** | 013-04-0036 | 17 | 22 | 69 |
| **6** | 019-01-0031 | 8 | 15 | 64 |
| **7** | 008-02-0029 | 15 | 9 | 69 |
| **8** | 052-01-0017 | 9 | 14 | 64 |
| **9** | 052-03-0026 | 11 | 9 | 64 |
| **10** | 013-09-0035 | 19 | 17 | 69 |
| **11** | 017-04-0043 | 16 | 21 | 69 |
| **12** | 258-02-0016 | 27 | 26 | 64 |
| **13** | 008-08-0028 | 12 | 13 | 69 |

**SAMI (Stress Absorbing Membrane Interlayer)**

SAMI consists of a single application of surface treatment coupled with an asphalt rubber binder. Only three projects offered sufficient data for a detailed performance analysis. Table 11 illustrates the predicted service lives for the treated and untreated sections. In order to identify the general trends reflected by this table, Figure 30 categorizes the level of improvement or disimprovement due to the use of SAMI into a structured histogram. As shown by these results, one section showed a positive improvement of about 10 years while the remaining two sections showed a negative contribution. Only one section showed an improvement of about 10 years and the other two evaluated sections showed negative improvement in the range of 3 to 5 years.

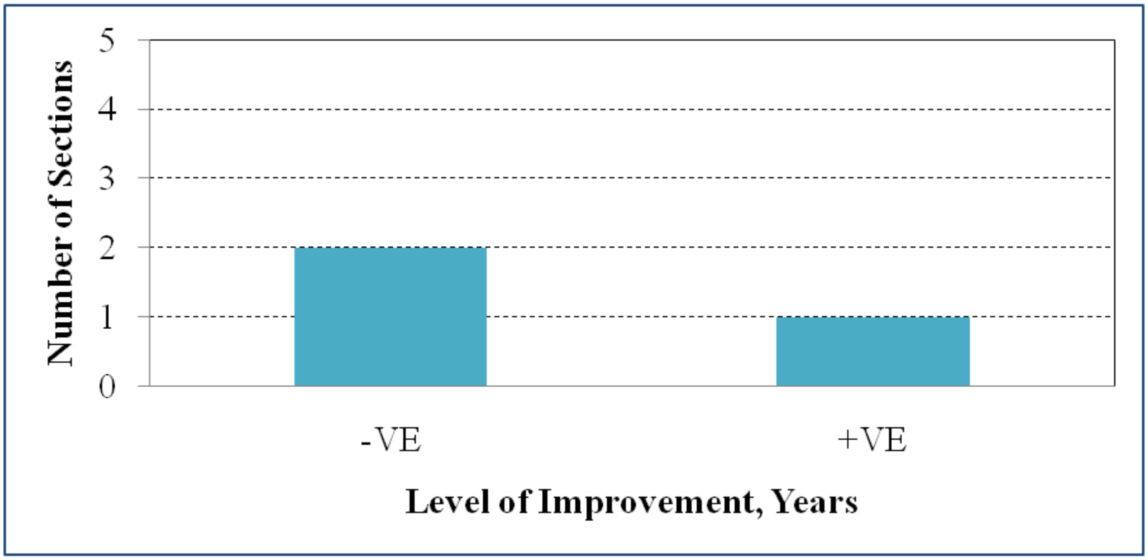



**Figure 30**
**Contribution of SAMI to pavement service lives**

**Paving Fabrics**

This study analyzed only three projects in the paving fabric category. All the projects where paving fabric was used showed a positive performance by improving the service life over untreated sections. Table 11 illustrates the predicted service lives for the treated and untreated sections. To identify the general trends in the tabulated results, Figure 31 categorizes the level of improvement or disimprovement, due to the use of paving fabric into a structured histogram. As shown by these results, 100 percent of the sites showed a positive improvement ranging from 4 to 5 years, while no sections showed a negative contribution or improvement, due to the treatment. The three sections collectively showed an improvement from 4 to 5 years; two of the sections showed an improvement of about 4 years, and one section showed an improvement of 5 years.

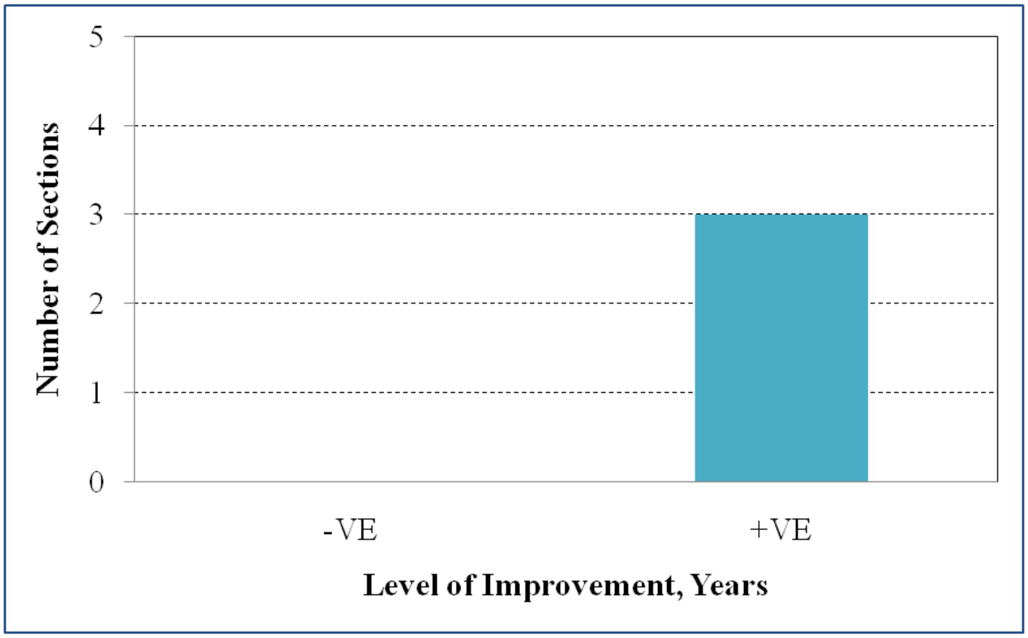



**Figure 31**
**Contribution of paving fabrics to pavement service lives**

**STRATA®**

STRATA® is technically known as a High Strain Asphalt Reflective Crack Relief Interlayer. This study analyzed three projects in this category to determine the levels of contribution to pavement performance. Projects with STRATA® showed either a positive improvement or no improvement in pavement service life; however, the no improvement case was considered a negative contribution. Table 11 illustrates the predicted service lives for the treated and untreated sections. Figure 32 categorizes the level of improvement or disimprovement due to the incorporation of STRATA®. The results show a positive improvement of 7 years, yet there were two sections showing a negative contribution. These two sections had no improvement due to the treatment. This was considered a negative impact.

**Table 11**
**Predicted average service lives**

| Side ID | Project No. (Treated) | Treatment | Predicted Service Life | | Trigger Value |
|---|---|---|---|---|---|
| | | | Treated Section | Untreated Section | |
| **1** | 020-09-0025 | SAMI | 18 | 23 | 69 |
| **2** | 413-30-0010 | SAMI | 19 | 22 | 64 |
| **3** | 019-05-0024 | SAMI | 23 | 13 | 69 |
| **4** | 067-09-0038 | Paving Fabrics | 18 | 14 | 69 |
| **5** | 451-07-0051 | Paving Fabrics | 14 | 10 | 75 |
| **6** | 451-05-0086 | Paving Fabrics | 15 | 10 | 75 |
| **7** | 451-08-0060 | STRATA® | 17 | 10 | 75 |
| **8** | 001-08-0035 | STRATA® | 10 | 10 | 69 |
| **9** | 261-04-0021 | STRATA® | 14 | 14 | 64 |

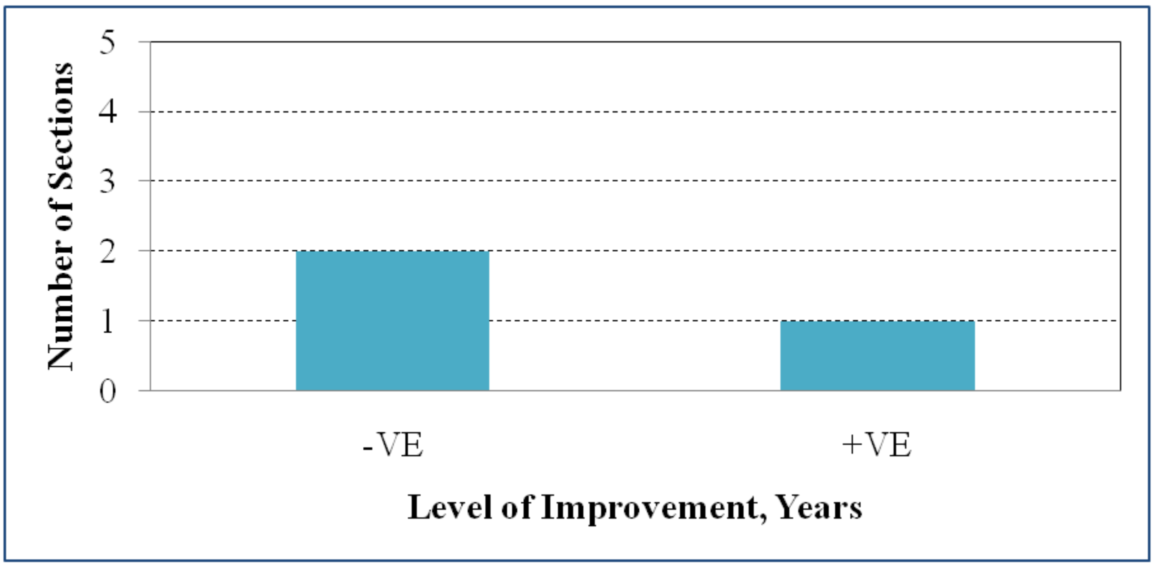



**Figure 32**
**Contribution of STRATA® to pavement service lives**

## Economic Analysis

### Saw and Seal

The cost data for the saw and seal as well as for the HMA overlays were obtained from actual bid items for each project. Figure 33 presents the percentage increase in the cost of the HMA overlay due to the saw and seal treatment. The increase in cost ranged from 0.5 to 21 percent, averaging 10 percent of the cost for the HMA overlay.

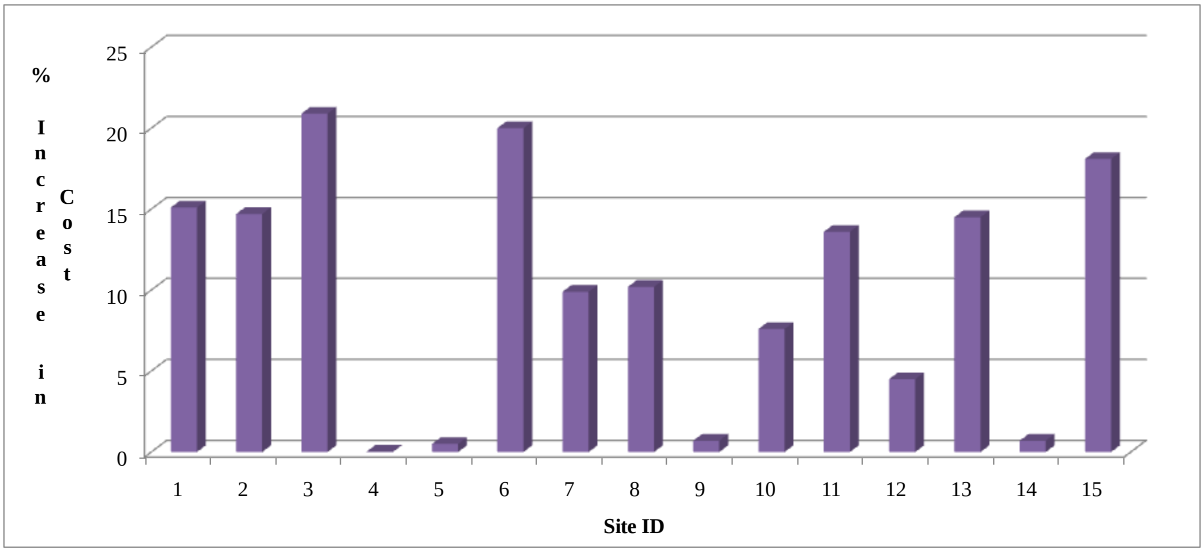



**Figure 33**
**Increase in cost of the HMA overlay due to saw and seal**

Figure 34 compares the cost of regular HMA overlays to the cost of treated HMA overlays, based on the TAC concept presented in equation (6). A positive cost difference (+VE) indicates that the use of saw and seal is found to be economical while a negative cost (-VE) difference indicates that the treatment method is not cost-effective compared to regular HMA overlays. As shown in this figure, the majority of the sections (80 percent) indicate that saw and seal is cost-effective, compared to regular HMA overlays. Based on these results, this study determined that this treatment method is cost-effective compared to regular HMA overlays. However, the effectiveness of this treatment method strongly depends on the success of the construction process in applying the treatment to the exact joint locations.

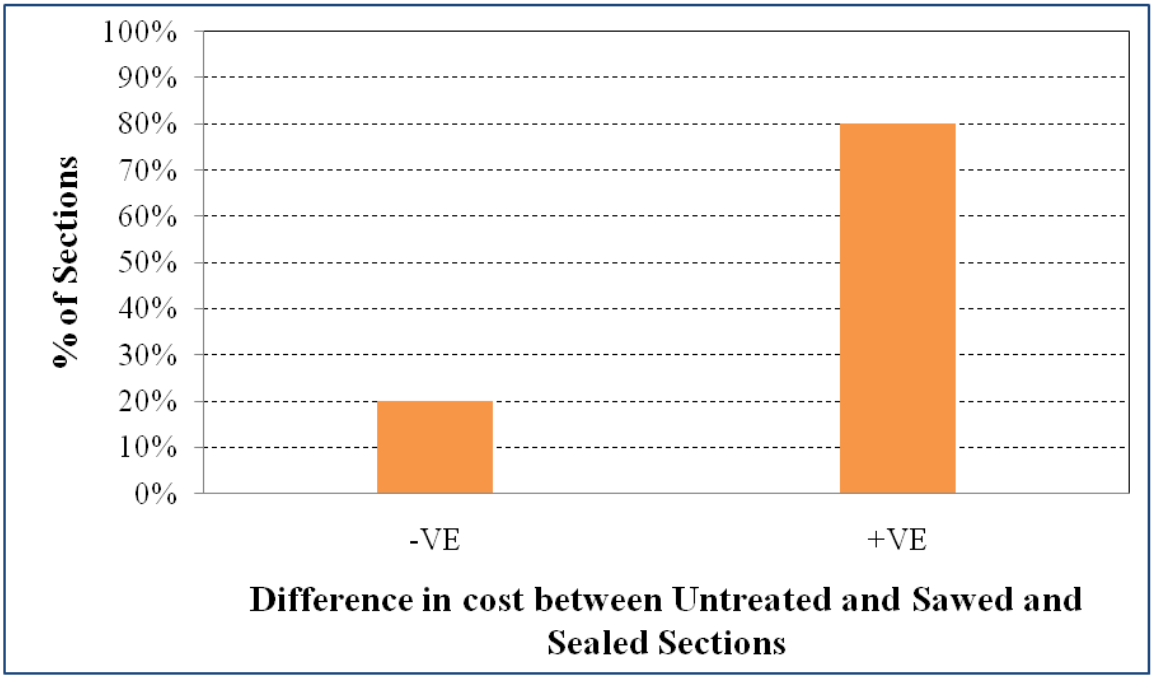



**Figure 34**
**Cost effectiveness of saw and seal treatment method**

### Chip Seal

Cost data for the chip seal, as well as for the HMA overlays, were obtained from actual bid items for each project. Figure 35 presents the percentage increase in the cost of the HMA overlay due to the chip seal treatment. The increase in cost ranged from 10 to 71 percent, averaging 25 percent of the cost of the HMA overlay. Figure 36 compares the cost of regular HMA overlays to the cost of treated HMA overlays, based on the TAC concept. In this figure, a positive cost difference indicates that the use of chip seal is economical, while a negative cost difference indicates that the treatment method is not cost-effective when compared to regular HMA overlays. As shown in this figure, the majority of the sections (75 percent) indicated that chip seal is cost-effective compared to regular HMA overlays. Based on these results, this study determined that the use of the chip seal treatment method is cost-effective as compared to regular HMA overlays.

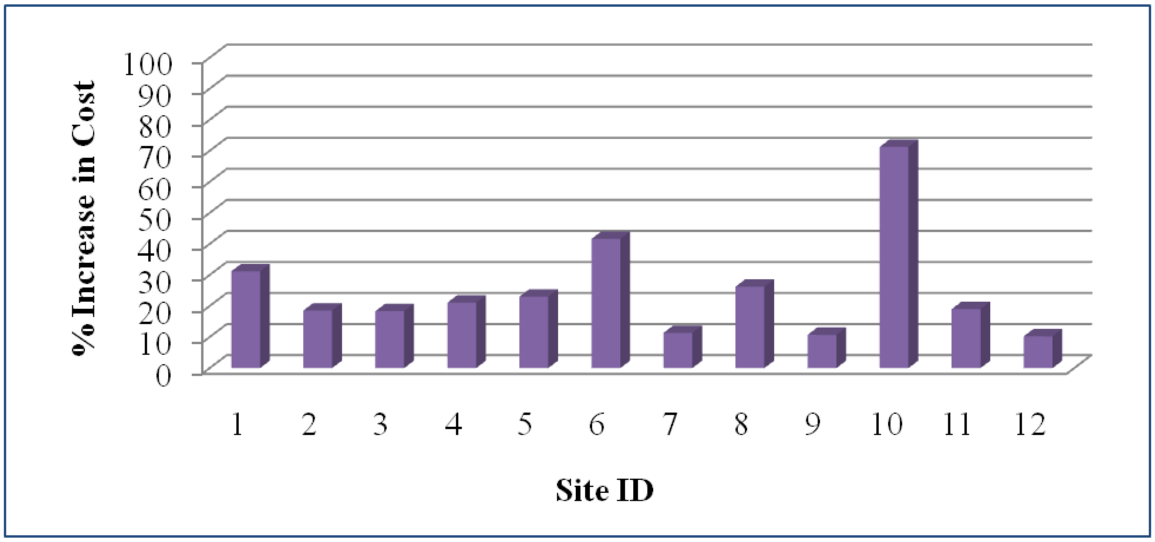



**Figure 35**
**Increase in cost of the HMA overlay due to chip seal**

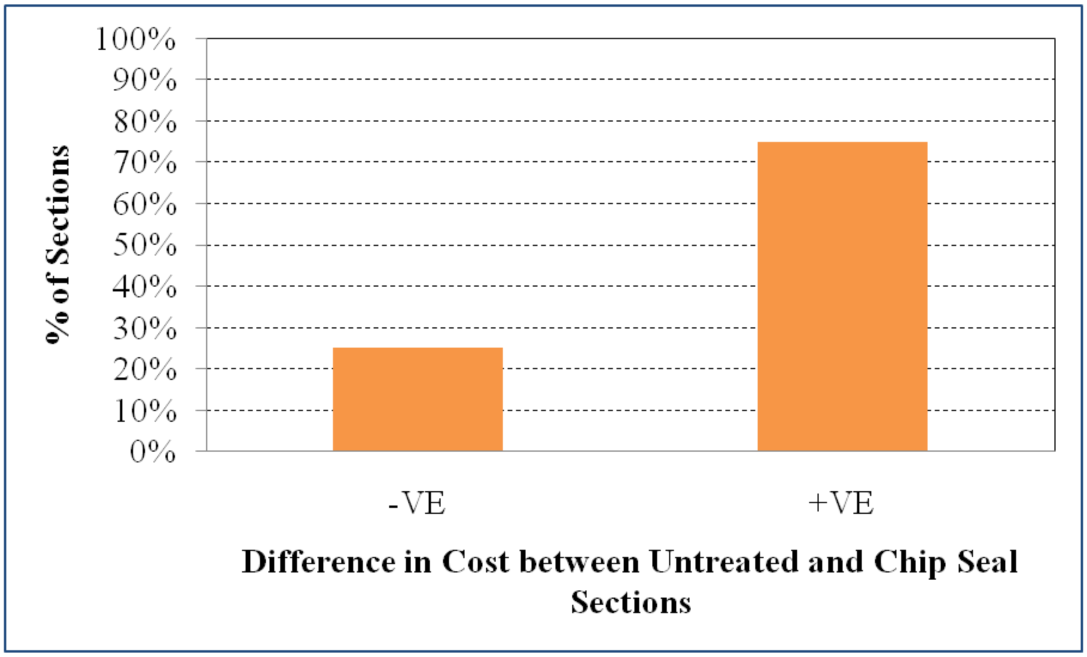



**Figure 36**
**Cost effectiveness of chip seal treatment method**

### Fiber-Glass Grid

Cost data for the road way reinforcement mesh as well as HMA overlays were obtained from actual bid items for each project. Figure 37 presents the percentage increase in the cost of the HMA overlay, due to the fiber-glass grid treatment. The increase in cost ranged from 1.6 to 128 percent averaging 48 percent of the HMA overlay cost.

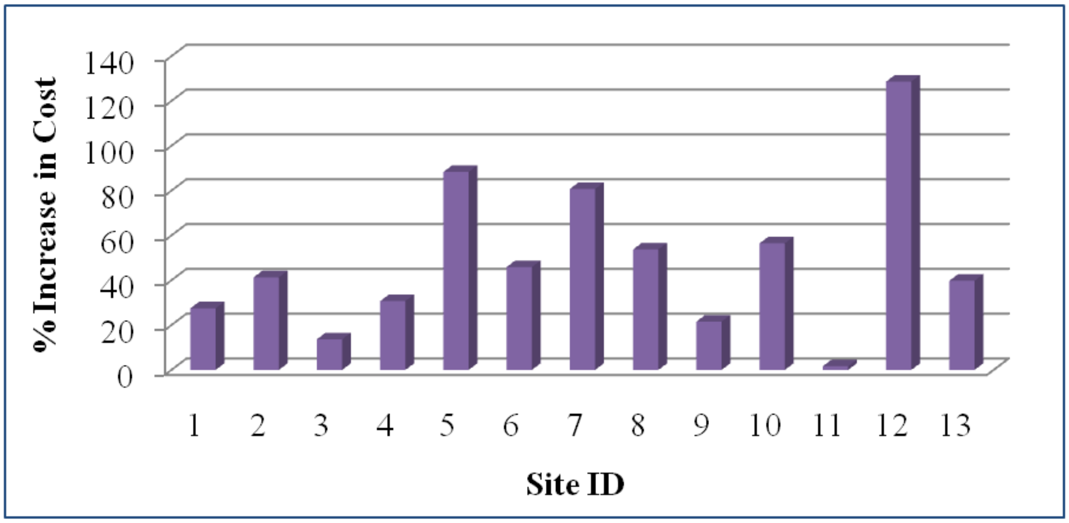



**Figure 37**
**Increase in cost of the HMA overlay due to fiber-glass grid**

Figure 38 compares the cost of reinforced HMA overlays to the cost of regular HMA overlays, based on the TAC concept. In this figure, a positive cost difference indicates that the use of fiber-glass grid is economical, while a negative cost difference indicates that the interlayer is not cost-effective when compared to regular HMA overlays. As shown in this figure, the majority of the sections (92 percent) indicate that fiber-glass grid is not cost-effective when compared to regular HMA overlays. Based on these results, the use of this interlayer will be more costly to highway agencies than economical as shown by the majority of sections in which the reinforcement was not cost-effective. To ensure that this interlayer system is used effectively in rehabilitated pavements, factors that contribute to the positive or negative contribution of fiber-glass grid to the pavement structure should be identified and incorporated into the design process. These factors include conditions of the existing pavement (e.g., load transfer efficiency at the joints and relative movements between the slabs); success of the installation to achieve adequate bonding and prevent delamination between the interlayer system and the surrounding layers; and pavement service conditions including traffic volume and thermal loading.

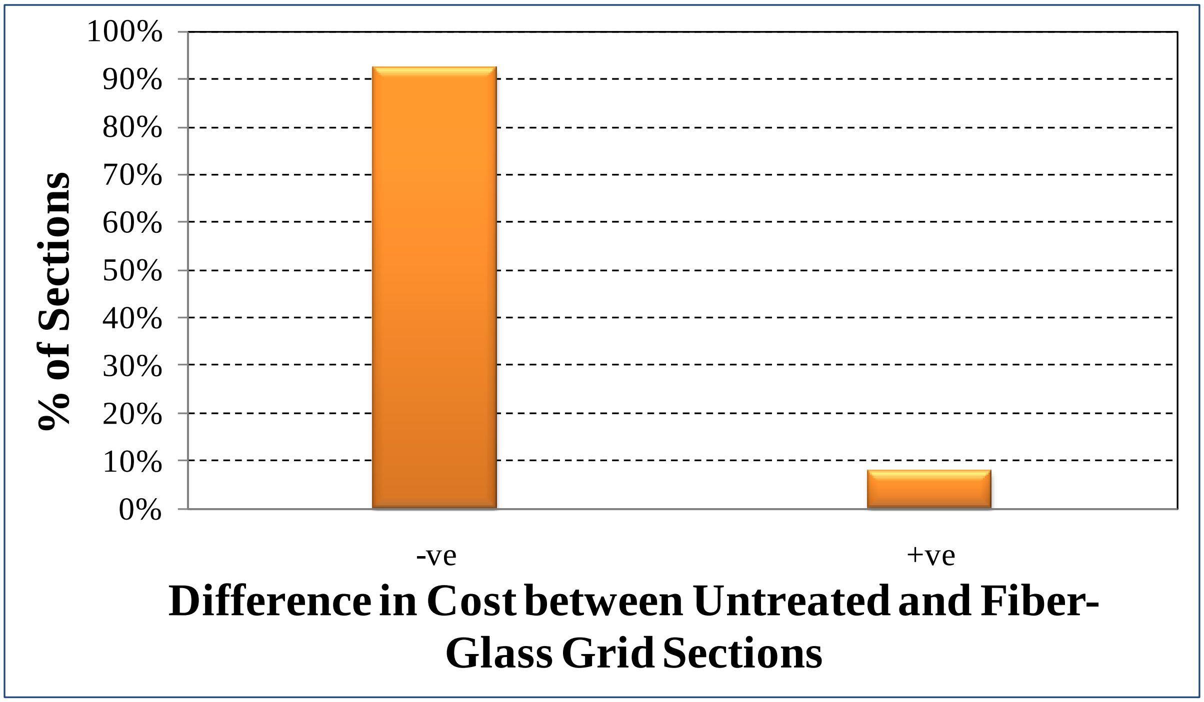



**Figure 38**
**Cost effectiveness of fiber-glass grid treatment method**

**SAMI (Stress Absorbing Membrane Interlayer)**

Cost data for SAMI as well as for HMA overlays were obtained from actual bid items for each project. Figure 39 presents the percentage increase in the cost of the HMA overlay due to the SAMI treatment (Sites 1, 2, and 3). The increase in cost ranged from 8 to 23 percent with an average of 14 percent of the HMA overlay cost. Two of the three sections indicated that SAMI is cost-effective as compared to regular HMA overlays. However, an additional evaluation is needed in order to determine the cost-effectiveness of this treatment method.

**Paving Fabrics**

Cost data for the paving fabrics as well as for the HMA overlays were obtained from actual bid items for each project. Figure 39 presents the percentage increase in the cost of the HMA overlay due to the fabric treatment (Sites 4, 5, and 6). The increase in cost ranged from 2 to 13 percent with an average of 8 percent of the cost of the HMA overlay. All of the sections indicated that paving fabric is cost-effective as compared to regular HMA overlays. However, an additional evaluation is needed in order to determine the cost-effectiveness of this treatment method.

**STRATA®**

Cost data for the high strain reflective crack relief interlayer (STRATA®) as well as for HMA overlays were obtained from actual bid items for each project. Figure 39 presents the percentage increase in the cost of the HMA overlay due to the STRATA® treatment (Sites 7, 8, and 9). The increase in cost ranged from 25 to 58 percent averaging 39 percent of the cost of the HMA overlay. The majority of the sections indicated that STRATA® is not as cost-effective compared to regular HMA overlays. An additional evaluation is needed in order to determine the cost-effectiveness of this treatment method.

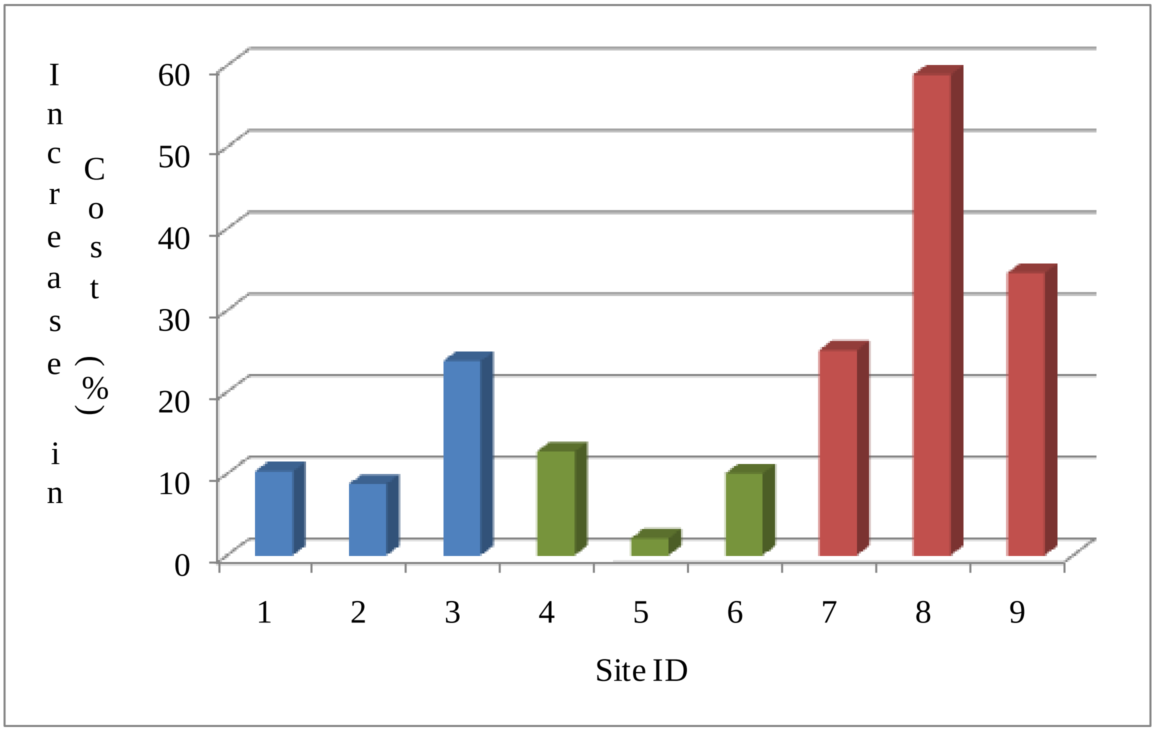
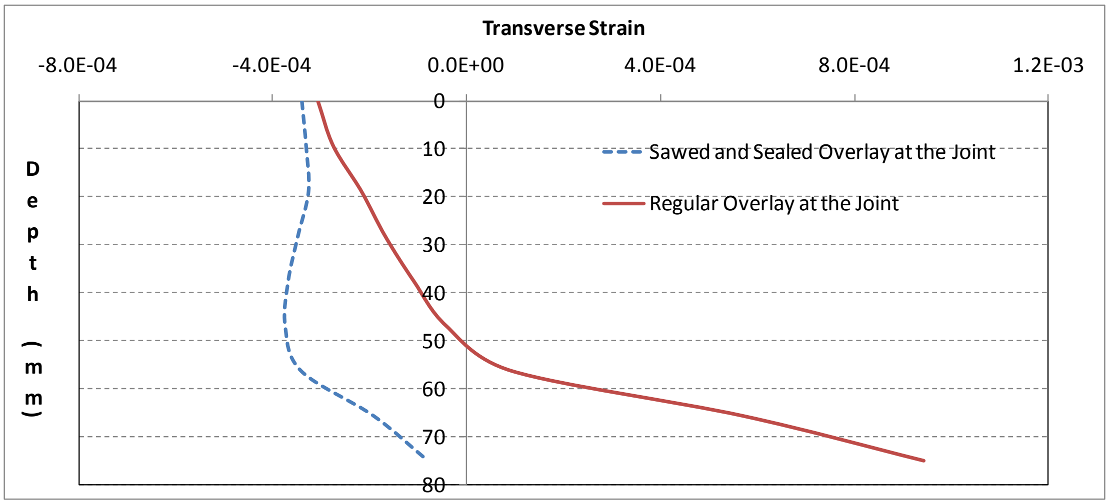



**Figure 39**
**Increase in cost of HMA overlay due to various treatments**

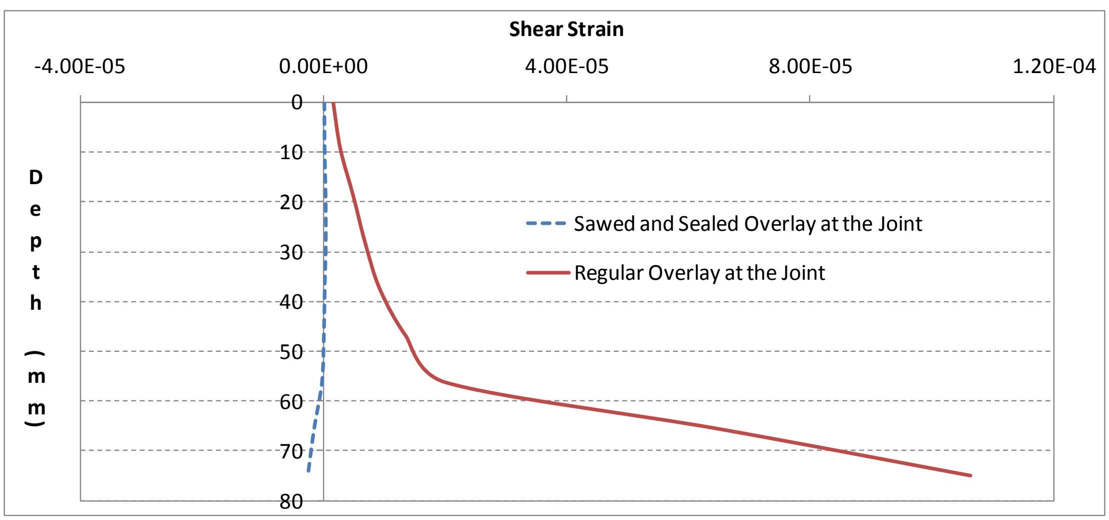
**Theoretical Investigation on Saw and Seal**

Figure 40 (a) and (b) illustrates the distributions of transverse strain and shear strain through the depth of the overlay at the PCC joint with and without the saw and seal method. Similarly, Figure 40 (c) and (d) illustrates the distribution of transverse strain and shear strain through the depth of the overlay at 17 in. from the PCC joint; this was the transverse location away from the joint with the maximum strain responses in the overlay. As shown in these figures, the use of the saw and seal method significantly reduced the strain levels at the PCC joint associated with Mode I loading [Figure 40 (a)] and Mode II loading [Figure 40 (b)].

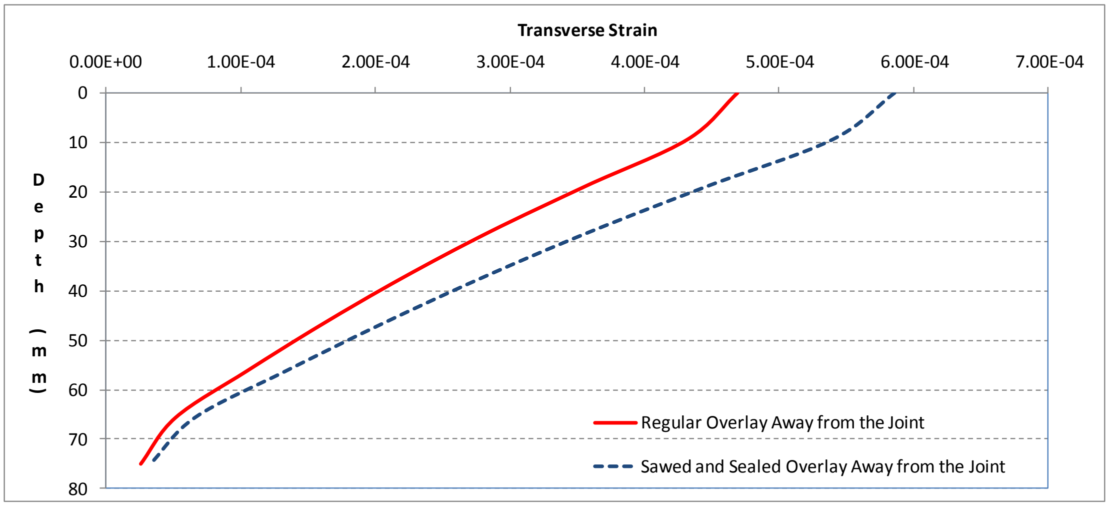
The high strain levels at the bottom of the HMA overlay constructed without the saw and seal method will result in crack initiation at the bottom of the overlay and crack propagation with load repetitions.  The transverse and shear strain distributions away from the joint were similar with and without saw and seal while being slightly greater when saw and seal was used.  It is determined from these results that the constructed joints in the HMA overlay allow it to move with the underlying layer and to dissipate the energy generated due to expansion and contraction in the concrete layer and wheel loading without cracking.



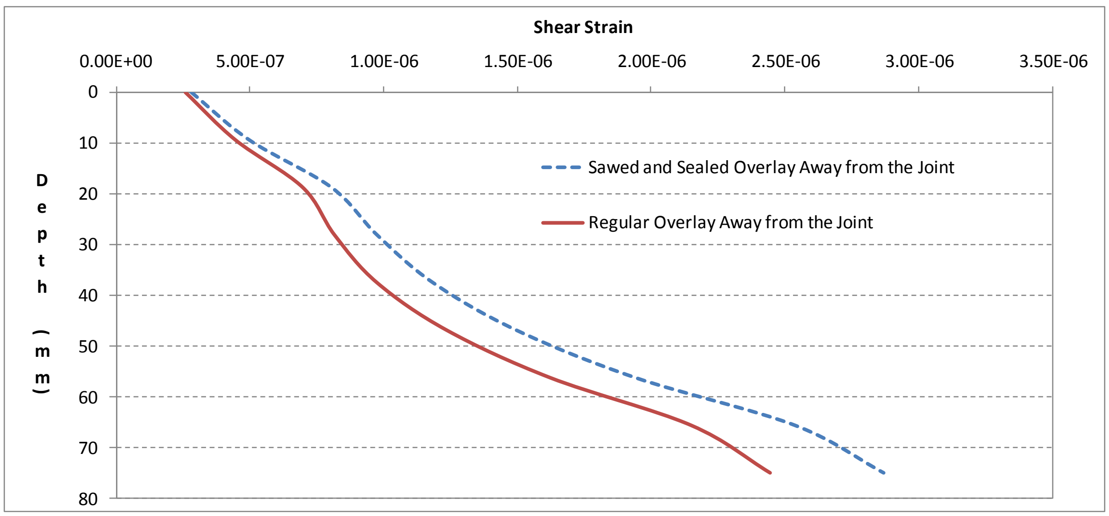

(a)




(b)




**(c)**



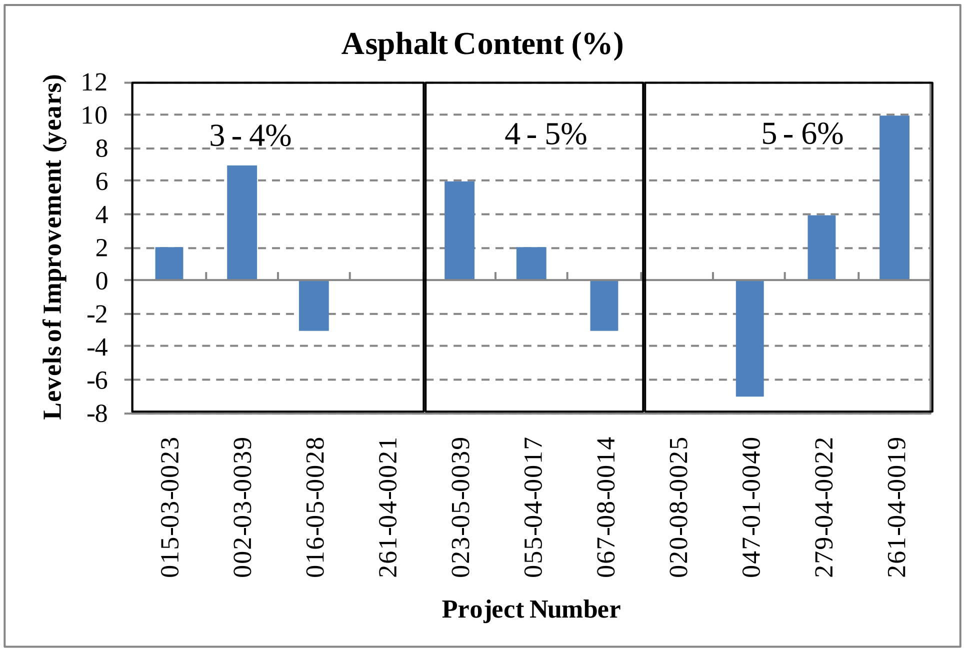

**(d)**

**Figure 40**

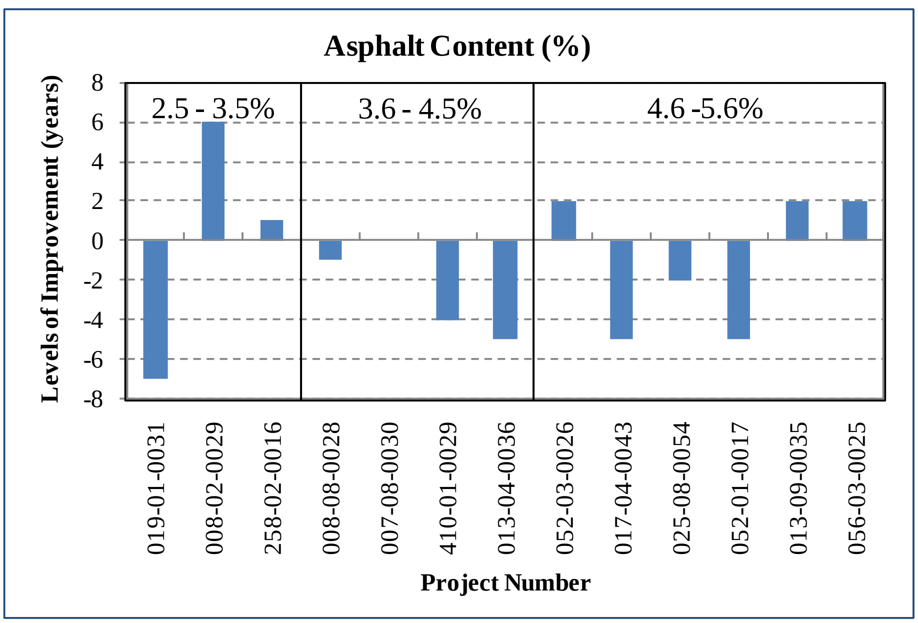
**Horizontal and shear strain distributions in the HMA overlay with and without the saw and seal method at the joint (a and b) and away from joint (c and d)**

## Effects of Material Properties on Performance of Pavement Sections

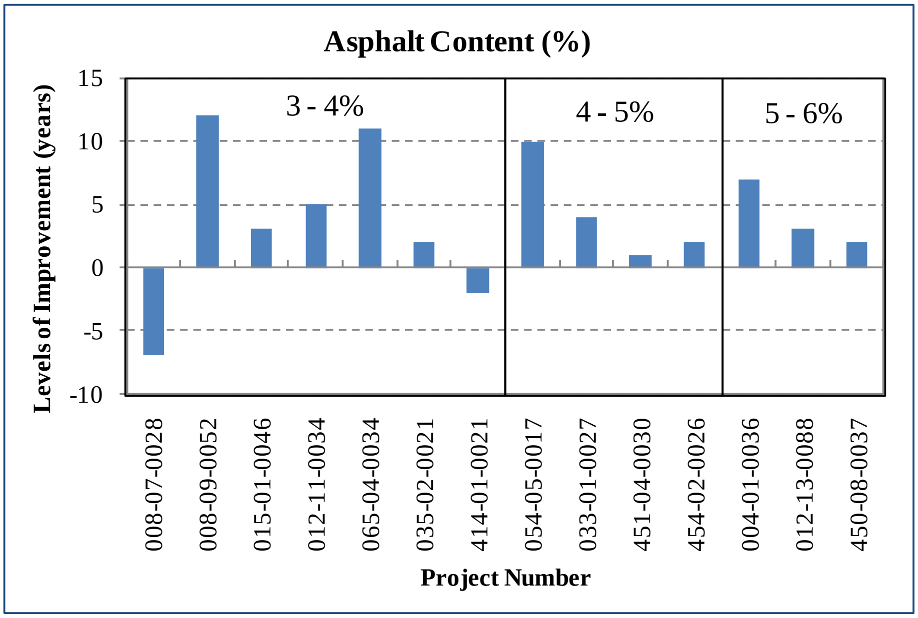
The effect of asphalt content on the performance of the analyzed pavement sections was investigated. Relevant data were extracted from the Materials section in the LADOTD Mainframe database. Figure 41 (a), (b), and (c) illustrates the effect of asphalt content on the levels of improvement or disimprovement for the sections treated with chip seal, fiber-glass grid, and saw and seal, respectively. As shown in these figures, there was no clear trend that would indicate that the increase in asphalt content improved the overlay performance against reflective cracking. However, additional data are needed to confirm the observed trends due to the variability in construction dates and binder types among the analyzed projects.




**(a) Chip Seal**




**(b) Fiber-Glass Grid**




**(c) Saw and Seal**

**Figure 41**
**Effect of asphalt content on performance levels**

## Reflective Crack Control Policy

Based on the findings and the results of this project, a reflective crack control policy was developed for the state. A choice is recommended for the districts between two treatment methods that were determined to be cost-effective for the climatic and operating conditions encountered in the state:

- **System A.** System A consists of sawing the overlaid asphaltic concrete pavement to create transverse and longitudinal joints at the exact locations of underlying PCC joints followed by sealing those at constructed joints.
  - *Construction Details:* Construction practices used in Louisiana were found successful in preventing double cracking, which is a critical factor when this treatment method is used. It is recommended that the overlay consists of a 2-in. binder-leveling course and a 1.5-in. surface course. All HMA lifts should be sawed and sealed. Success of saw and seal depends on applying the treatment at the exact locations of the joints. Prior to overlay, existing joints on the concrete pavement should be located and marked accurately by placing a hub with a tack even with the ground at each edge of shoulder.

- **System B.** System B consists of applying an asphaltic surface treatment (chip seal) as a crack relief interlayer prior to the HMA overlay. Chip seal may also be used as an interlayer on overlays of composite pavements assuming that the existing overlay is not removed up to the depth of the concrete. Typical AST interlayers used in Louisiana are known as Type E [72].
    - *Construction Details:* Additional research is needed to optimize the construction specifications of this interlayer as well as the type and content of asphalt binders used in the installation. It is also recommended that the overlay consists of a 2-in. binder-leveling course and a 1.5-in. surface course.

Past research results at LTRC also showed that the use of crumb-rubber modified (CRM) wet process in HMA is an effective method to control crack propagation *[79]*. Therefore, the proposed reflective cracking control policy should recommend the use of CRM or polymer-modified HMA in overlays placed on top of composite pavements to increase the pavement resistance to cracking.

# CONCLUSIONS

The objective of this study was to evaluate and compare different reflective cracking control treatments by evaluating the performance, constructability, and cost-effectiveness of pavements built with these treatments across the state.  In total, the performance of 50 different sites that were constructed with various treatments was evaluated for a period ranging from 4 to 18 years. Results of this analysis assessed the benefits of these crack control techniques in terms of performance, economic worthiness, constructability, and long-term benefits. Based on the results of the performance and cost analysis, conclusions were drawn for each of the treatment method.

Saw and Seal:

- The majority of the sites showed a positive improvement due to the use of saw and seal. Forty percent of the sections showed an improvement from 1 to 3 years and 47 percent of the evaluated sections showed an improvement from 4 to 12 years. The average level of improvement to the pavement service life due to the use of saw and seal was 4 years.
- The vast majority of the sections (80 percent) indicated that saw and seal is cost-effective as compared to regular HMA overlays. The increase in cost of overlay due to usage of saw and seal treatment ranged from 0.5 to 21 percent.
- The effectiveness of saw and seal treatment method depends on the success of the construction process to ensure that the treatment is applied at the exact locations of the joints.

Chip Seal:

- The majority of the sites showed a positive improvement due to the use of chip seal. Twenty-five percent of the sections showed an improvement from 1 to 3 years and 33 percent of the evaluated sections showed an improvement from 4 to 10 years. The average level of improvement to the pavement service life due to the use of chip seal was 2 years.
- The vast majority of the sections (75 percent) indicated that chip seal is cost-effective as compared to regular HMA overlays. The increase in cost of overlay due to usage of chip seal treatment ranged from 10 to 71 percent.

Fiber-Glass Grid:

- The majority of the sites showed a negative contribution due to the use of fiber-glass grid. Twenty three percent of the sections showed a disimprovement from 1 to 3 years and 39 percent of the evaluated sections showed a disimprovement from 3 to 9 years.
- The vast majority of the sections (92 percent) indicated that fiber-glass grid is not cost-effective as compared to regular HMA overlays. The increase in the cost of overlay due to the usage of fiber-glass grid ranged from 1.6 to 128 percent.

SAMI, STRATA®, and Fabrics:

SAMI and high strain asphalt crack relief interlayer (STRATA®) showed mixed results in terms of performance and cost effectiveness. On the other hand, paving fabrics exhibited promising performance. However, there were not enough projects available under stress absorbing membrane interlayer, paving fabrics, and high strain asphalt reflective crack relief interlayer categories in order to assess the effectiveness of these treatment methods.

# RECOMMENDATIONS

Based on the findings and the results of this project, the field performance and cost-effectiveness of various treatment methods across the state were evaluated. Results should be implemented by the Department through the development of a crack control policy that recommends specific rehabilitation strategies for composite pavements. A crack control policy was developed based on the results of this project. In general, it is recommended that the overlay of an existing PCC pavement consists of a 2-in. binder-leveling course and a 1.5-in. surface course. A choice is recommended between two treatment methods that were determined to be cost-effective for the climatic and operating conditions encountered in the state:

- **System A.** System A consists of sawing the overlaid asphaltic concrete pavement to create transverse and longitudinal joints at the exact locations of underlying PCC joints followed by sealing of those constructed joints.
- **System B.** System B consists of applying an asphaltic surface treatment (chip seal) as a crack relief interlayer prior to the HMA overlay.

Results of this study assessed the performance and cost-effectiveness of various treatment methods used to prevent and delay reflective cracking in composite pavements based on existing sections built with these treatments across the state. A second phase for this project is recommended to conduct a controlled field evaluation that would assess the conditions of the existing pavements prior to rehabilitation and application of the treatments. A designed experiment would also allow refining and modifying the proposed crack control policy based on the level of distresses prior to rehabilitation, load transfer efficiency, type of pavement structure, age, climate, and traffic. Future research activities will also allow identifying the design and operating factors that control the performance of crack control treatment methods including fiber-glass grid, SAMI, and STRATA®.

# ACRONYMS, ABBREVIATIONS, AND SYMBOLS

| | |
|---|---|
| AADT | Annual Average Daily Traffic |
| AASHTO | American Association of State Highway and Transportation Officials |
| ADT | Average Daily Traffic |
| ARAN | Automatic Road Analyzer |
| AST | Asphaltic Surface Treatment |
| cm | centimeter(s) |
| CRCP | Continuously Reinforced Concrete Pavement |
| CRM | Crumb-rubber modified |
| ESAL | Equivalent Single Axle Load |
| FE | Finite Element |
| FHWA | Federal Highway Administration |
| ft. | foot (feet) |
| FWD | Falling Weight Deflectometer |
| GPR | Ground Penetrating Radar |
| HMA | Hot Mix Asphalt |
| HPMS | Highway Performance Monitoring System |
| IRF | International Road Federation |
| IRI | International Roughness Index |
| in. | inch(es) |
| ISAC | Interlayer Stress Absorbing Composite |
| JRCP | Joint Reinforced Concrete Pavement |
| ksi | Kilo pounds per square inch |
| LADOTD | Louisiana Department of Transportation and Development |
| lb. | pound(s) |
| LTPP | Long Term Pavement Performance |
| LTRC | Louisiana Transportation Research Center |
| m | meter(s) |
| NCAT | National Center for Asphalt Technology |
| NHS | National Highway of Significance |
| NMAS | Nominal Maximum Aggregate Size |
| PCC | Portland Cement Concrete |
| PCI | Pavement Condition Index |
| PMS | Pavement Management System |
| psi | Pounds per square inch |

| | |
|---|---|
| PVC | Poly Vinyl Chloride |
| RC | Number of Cracks Reflected |
| RCI | Reflective Cracking Index |
| RDD | Rolling Dynamic Deflectometer |
| RHS | Rural Highway of Significance |
| SAMI | Stress Absorbing Membrane Interlayer |
| SBS | Styrene Butadiene Styrene |
| SHS | State Highway of Significance |
| SMA | Stone Matrix Asphalt |
| TAC | Total Annual Cost |
| TOPS | Tracking of Projects System |
| USDOT | United States Department of Transportation |

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# APPENDIX

## List of Identified Pavement Sections

The following tables present a summary of the information collected for the identified pavement sections.

**Table 12**
**List of identified pavement sections**

**Fiber-Glass Grid Projects (WO: Date of Work Order)**

| Project Number | District | Parish | Begin Log Mile | End Log Mile | Pavement Type | Traffic | Construction Date | Route |
|---|---|---|---|---|---|---|---|---|
| 006-02-0062 | 2 | Jefferson | 0 | 3.46 | Primary | 48,300 | 11/17/2004 | US 90 |
| 742-26-0046 | 2 | Jefferson | 0 | 0 | City Street | 32,546 | 7/2/2004 | N/A |
| 742-26-0048 | 2 | Jefferson | 0.000 | 0.000 | City Street | 22,400 | 3/2/2007 | N/A |
| 742-26-0050 | 2 | Jefferson | 0 | 0 | City Street | 10,650 | 2/17/2005 | N/A |
| 742-26-0052 | 2 | Jefferson | 0 | 0 | City Street | N/A | 8/31/2007 | N/A |
| 742-26-0054 | 2 | Jefferson | 0 | 0 | City Street | N/A | 03/02/2009 WO | N/A |
| 742-26-0055 | 2 | Jefferson | 0.000 | 0.000 | City Street | N/A | 6/21/2006 | N/A |
| 742-26-0057 | 2 | Jefferson | 0 | 0 | City Street | 23,500 | 7/6/2004 | N/A |
| 742-26-0058 | 2 | Jefferson | 0 | 0.25 | City Street | 18,300 | 5/7/2007 | N/A |
| 742-26-0059 | 2 | Jefferson | 0.000 | 0.000 | City Street | N/A | 7/10/2006 | N/A |
| 742-26-0060 | 2 | Jefferson | 0 | 0 | City Street | 32,564 | 1/19/2005 | N/A |
| 742-26-0063 | 2 | Jefferson | 0.000 | 0.000 | City Street | N/A | 8/14/2006 | N/A |
| 742-26-0066 | 2 | Jefferson | 0 | 0 | City Street | N/A | Proposed | N/A |
| 742-36-0124 | 2 | Orleans | 0 | 0 | City Street | 30,700 | 02/19/2008 | N/A |
| 742-36-0125 | 2 | Orleans | 0 | 0 | City Street | N/A | 02/19/2008 | N/A |

| Project Number | District | Parish | Begin Log Mile | End Log Mile | Pavement Type | Traffic | Construction Date | Route |
|---|---|---|---|---|---|---|---|---|
| 742-36-0127 | 2 | Orleans | 0 | 0 | City Street | N/A | 02/19/2008 | N/A |
| 742-36-0128 | 2 | Orleans | 0.000 | 0.000 | City Street | N/A | Inactive | N/A |
| 062-01-0018 | 2 | Jefferson | 0 | 0.58 | Secondary | 41,894 | 1/13/1999 | LA 18 |
| 410-01-0029 | 2 | Orleans | 0 | 0.25 | Farm to Market | 7,650 | 1/13/1999 | LA 428 |
| 246-01-0035 | 2 | Terrebonne | 1.89 | 6.89 | Secondary | 12,380 | 6/6/1997 | LA 57 |
| 246-01-0052 | 2 | Terrebonne | 7.5 | 17.35 | Secondary | 4,954 | 1/6/2000 | LA 57 |
| 056-03-0025 | 3 | St. Martin | 0.000 | 4.110 | Secondary | 6,043 | 10/30/1996 | LA 31 |
| 008-05-0035 | 3 | St. Landry | 7.73 | 16.057 | Secondary | 3,000 | 10/3/2008 | US 71 |
| 056-03-0025 | 3 | St. Martin | 0 | 4.11 | Secondary | 4,607 | 10/30/1996 | LA 31 |
| 025-08-0054 | 4 | Caddo | 6.627 | 8.570 | Primary | 28,500 | 10/2/2003 | US 171 |
| 742-37-0007 | 5 | Ouachita | 0 | 0 | City Street | 6,841 | 10/1/2004 | N/A |
| 114-03-0026 | 8 | Natchitoches | 9.181 | 13.82 | Primary | 3,700 | 1/16/2009 | LA 117 |
| 026-06-0046 | 58 | Franklin | 10.37 | 15.622 | Primary | 9,584 | 4/14/1997 | LA 15 |
| 052-01-0018 | 61 | Pointe Coupee | 6.830 | 12.748 | Primary | 12,700 | 01/05/2007 | LA 1 |
| 052-03-0026 | 61 | Pointe Coupee | 0.000 | 15.100 | Primary | 6,500 | 10/17/2002 | LA1 |
| 060-02-0031 | 61 | EBR | 1.197 | 6.428 | Primary | 27,500 | 11/27/2006 | LA 67 |
| 007-07-0046 | 61 | Ascension | 11.941 | 12.956 | Primary | 29,300 | 9/15/2005 | US 61 |
| 007-07-0051 | 61 | Ascension | 12.73 | 13.52 | Primary | 36,100 | 05/08/2009 | US 61 |
| 050-05-0019 | 61 | Ascension | 0 | 6.43 | Primary | 12,400 | 5/27/2005 | LA 1 |
| 256-06-0010 | 61 | Ascension | 1.382 | 1.834 | Secondary | 9,700 | 7/31/2008 | LA 44 |
| 005-02-0049 | 61 | Assumption | 0.681 | 3.59 | Primary | 1,400 | 10/1/2008 | LA 182 |
| 007-08-0030 | 61 | EBR | 4.113 | 5.82 | Primary | 41,000 | 1/25/2005 | US 61 |

| Project Number | District | Parish | Begin Log Mile | End Log Mile | Pavement Type | Traffic | Construction Date | Route |
|---|---|---|---|---|---|---|---|---|
| 019-01-0031 | 61 | EBR | 3.401 | 4.56 | Secondary | 26,787 | 10/28/2002 | US 61 |
| 060-02-0031 | 61 | EBR | 1.197 | 6.248 | Primary | 27,500 | 11/27/2006 | LA 67 |
| 077-05-0049 | 61 | EBR | 8.08 | 8.71 | Farm to Market | 30,200 | 8/18/2006 | LA 73 |
| 450-10-0134 | 61 | EBR | 1.38 | 2.32 | Interstate | 161,800 | 10/22/2008 | I-10 |
| 060-03-0022 | 61 | East Feliciana | 7.99 | 12.59 | Primary | 9,600 | 12/15/2004 | LA 67 |
| 050-06-0066 | 61 | Iberville | 14.490 | 16.820 | Primary | 30,000 | 11/14/2005 | LA 1 |
| 008-02-0029 | 61 | Pointe Coupee | 1.56 | 8.74 | Primary | 15,300 | 11/14/2003 | US 190 |
| 052-01-0017 | 61 | Pointe Coupee | 0.181 | 6.83 | Primary | 9,100 | 11/9/2004 | LA 1 |
| 050-07-0067 | 61 | West Baton Rouge | 2.34 | 8.28 | Primary | 38,500 | 5/27/2005 | LA 1 |
| 061-04-0057 | 61 | West Feliciana | 2 | 2.26 | Secondary | 5,400 | 2/21/2003 | LA 10 |
| 013-04-0036 | 61 | EBR | 0 | 3.07 | Primary | 25,800 | 3/2/2000 | US 61 |
| 019-01-0031 | 61 | EBR | 3.401 | 4.56 | Secondary | 25,965 | 10/18/2002 | US 61 |
| 052-03-0026 | 61 | Pointe Coupee | 0 | 15.1 | Primary | 2,999 | 10/17/2002 | LA 1 |
| 061-04-0057 | 61 | West Feliciana | 0 | 2.26 | Secondary | 5,212 | 2/21/2003 | LA 10 |
| 017-04-0043 | 62 | Tangipahoa | 2.270 | 4.000 | Secondary | 25,242 | 8/23/2000 | US 51 |
| 013-09-0035 | 62 | Tangipahoa | 0.970 | 4.967 | Primary | 10,200 | 1/20/1995 | US 190 |
| 046-03-0064 | 2 | St. Bernard | 0 | 2.91 | Primary | 26,348 | 9/11/2002 | LA 46 |
| 008-08-0028 | 8 | Rapides | 0.000 | 4.573 | Primary | N/A | 1/13/2003 | US 71 |
| 258-02-0016 | 61 | E. Baton Rouge | 3.180 | 4.880 | Farm to Market | 22,300 | 06/11/1997 | LA 427 |

**Saw and Seal Projects**

| Project Number | Begin Log Mile | End Log Mile | District | Parish | Pavement Type | Construction Date | Route |
|---|---|---|---|---|---|---|---|
| 046-31-0048 | 0.49 | 2 | 2 | Orleans | Primary | 4/15/2004 | LA 39 |
| 455-07-0030 | 32.512 | 36.540 | 4 | Caddo | Interstate | 09/24/2007 | I-49 |
| 195-04-0028 | 0 | 3.3 | 7 | Calcasieu | Primary | 3/17/2006 | LA 385 |
| 008-07-0028 | 10.392 | 11.540 | 8 | Avoyelles | Primary | 1/13/2003 | US 71 |
| 052-07-0014 | 0.130 | 6.680 | 8 | Avoyelles | Primary | 8/20/2004 | LA 1 |
| 053-04-0033 | 7.990 | 11.180 | 8 | Natchitoches | Primary | 9/13/2000 | LA 1 |
| 008-30-0048 | 0.765 | 1.465 | 8 | Rapides | Primary | 8/11/2006 | US 71 |
| 008-07-0028 | 10.392 | 11.54 | 8 | Avoyelles | Primary | 1/13/2003 | US 71 |
| 022-05-0050 | 3.814 | 9.955 | 58 | LaSalle | Primary | 6/26/2008 | US 84 |
| 020-02-0033 | 8.330 | 18.210 | 58 | Tensas | Primary | 9/17/2008 | US 65 |
| 817-20-0025 | 2.235 | 3.493 | 61 | EBR | Primary | 1/14/2005 | US 61 |
| 415-02-0013 | 2.74 | 4 | 62 | Tangipahoa | Secondary | 2/21/2003 | LA 40 |
| 424-05-0095 | 15.86 | 17.56 | 3 | St. May | Primary | 4/22/1999 | US 90 |
| 019-01-0030 | 0 | 3.485 | 61 | EBR | Primary | 4/28/1999 | US 61 |
| 001-08-0035 | 0.6 | 1.478 | 5 | Lincoln | Primary | 3/22/2004 | US 80 |
| 003-05-0034 | 0.53 | 3.61 | 7 | Calcasieu | Primary | 4/26/2006 | US 90 |
| 003-07-0028 | 0.260 | 9.500 | 7 | Jeff Davis | Primary | 8/21/2006 | US 90 |
| 003-08-0021 | 0 | 1.43 | 7 | Jeff Davis | Primary | 6/7/2004 | US 90 |
| 012-11-0035 | 10.682 | 15.133 | 3 | St.Landry | Primary | 7/17/2006 | US 190 |
| 014-02-0018 | 0.007 | 0.648 | 7 | Jeff Davis | Primary | 5/11/2005 | US 165 |

| Project Number | Begin Log Mile | End Log Mile | District | Parish | Pavement Type | Construction Date | Route |
|---|---|---|---|---|---|---|---|
| 023-02-0025 | 6.342 | 10.812 | 8 | Grant | Primary | 8/23/2005 | US 167 |
| 025-01-0040 | 7.158 | 9.383 | 8 | Vernon | Primary | 7/26/2004 | US 171 |
| 040-03-0026 | 0 | 9.147 | 8 | Grant | Secondary | 9/1/2007 | LA 8 |
| 050-07-0068 | 0 | 2.34 | 61 | WBR | Primary | 11/14/2005 | LA 1 |
| 052-07-0014 | 0.13 | 6.68 | 8 | Avoyelles | Primary | 8/20/2004 | LA1 |
| 052-07-0015 | 6.54 | 10.228 | 8 | Avoyelles | Primary | 5/13/2005 | LA 1 |
| 053-03-0036 | 4.955 | 11.517 | 8 | Natchitoches | Primary | 5/31/2006 | LA 1 |
| 054-04-0024 | 9.150 | 17.630 | 7 | Jeff Davis | Interstate | 4/10/2007 | LA 26 |
| 057-02-0029 | 7.97 | 9.148 | 3 | Acadia | Primary | 6/22/2007 | LA 13 |
| 065-91-0026-B | 6.84 | 8.48 | 2 | Terrebonne | Secondary | 6/13/2007 | LA 24 |
| 246-01-0061-A | 0.14 | 2.4 | 2 | Terrebonne | Secondary | 6/13/2007 | LA 57 |
| 195-04-0028 | 0 | 3.3 | 7 | Calcasieu | Primary | 3/17/2006 | LA 385 |
| 207-03-0013 | 0.3 | 1.99 | 3 | Vermilion | Secondary | 3/3/2004 | LA 35 |
| 236-02-0021 | 0 | 3.5 | 3 | Iberia | Secondary | 8/15/2005 | LA 85 |
| 238-02-0020 | 6.13 | 6.36 | 3 | St.Martin | Primary | 3/17/2006 | LA 96 |
| 432-01-0020 | 15.287 | 22.702 | 8 | Sabine | Secondary | 8/1/2003 | LA 191 |
| 432-01-0021 | 22.267 | 28.12 | 8 | Sabine | Secondary | 11/22/2005 | LA 191 |
| 450-18-0088 | 0 | 6.62 | 62 | St.Tammany | Interstate | 12/15/2006 | I 10 |
| 451-03-0059 | 11.56 | 13.68 | 4 | Webster | Interstate | 3/22/2005 | I 20 |
| 451-05-0101 | 21.279 | 27.33 | 5 | Lincoln | Interstate | 6/7/2005 | I 20 |
| 451-06-0124 | 11.898 | 16.824 | 5 | Ouachita | Interstate | 9/21/2006 | I 20 |
| 451-07-0063 | 21.279 | 26.601 | 5 | Richland | Interstate | 12/11/2006 | I 20 |
| 451-08-0065 | 5.063 | 16.124 | 5 | Madison | Interstate | 12/17/2004 | I 20 |
| 802-05-0013 | 3.69 | 8.37 | 7 | Allen | Farm to Market | 12/7/2006 | LA 372 |
| 802-05-0014 | 0 | 3.69 | 7 | Allen | Farm to Market | 9/1/2007 | LA 372 |

| Project Number | Begin Log Mile | End Log Mile | District | Parish | Pavement Type | Construction Date | Route |
|---|---|---|---|---|---|---|---|
| 802-12-0009 | 0 | 1.92 | 7 | Allen | Farm to Market | 11/21/2005 | LA 1152 |
| 826-04-0012 | 0 | 2.85 | 2 | Jefferson | Farm to Market | 4/21/2006 | LA 6119 |
| 826-13-0020 | 0 | 4.2 | 2 | Jefferson | Farm to Market | 12/27/2006 | LA 541 |
| 834-13-0008 | 0 | 1.575 | 5 | Morehouse | Secondary | 12/20/2004 | LA 830-4 |
| 838-01-0008 | 0 | 3.92 | 2 | Plaquemine | Farm to Market | 10/12/2007 | LA 3017 |
| 840-46-0001 | 0 | 3.26 | 8 | Rapides | Farm to Market | 3/3/2006 | LA 1243 |
| 855-08-0048 | 0 | 2.02 | 2 | Terrebonne | Farm to Market | 10/12/2007 | LA 661 |
| 855-14-0016 | 0.13 | 0.73 | 2 | Terrebonne | Farm to Market | 6/30/2006 | LA 3087 |
| 053-05-0045 | 4.077 | 5.183 | 8 | Natchitoches | Secondary | 1/16/2009 | LA 3191 |
| 022-03-0052 | 0.134 | 5.793 | 8 | Winn | Primary | 05/08/2009 | US 84 |
| 020-04-0042 | 4.633 | 8.899 | 58 | Tensas | Primary | 5/21/2007 | US 65 |
| 001-09-0067 | 13.511 | 13.754 | 5 | Ouachita | Primary | 3/30/2007 | US 80 |
| 837-19-0001 | 0.253 | 0.417 | 5 | Ouachita | Secondary | 3/30/2007 | US 80 |
| 001-09-0068 | 9.720 | 10.110 | 5 | Ouachita | Primary | 7/14/2009 | US 80 |
| 002-01-0041 | 0 | 1.2 | 5 | Ouachita | Primary | 8/4/2008 | US 80 |
| 001-09-0081 | 18.26 | 18.97 | 5 | Ouachita | Primary | 10/2/2007 | US 80 |
| 005-05-0074 | 5.64 | 6.99 | 2 | Terrebonne | Primary | 11/26/2007 | LA 182 |
| 009-03-0029 | 5.74 | 12.012 | 8 | Grant | Primary | 6/2/2008 | US 171 |
| 009-31-0009 | 0.000 | 5.614 | 8 | Grant | Farm to Market | 1/23/2008 | LA 492 |
| 012-11-0037 | 15.310 | 18.670 | 3 | St.Landry | Primary | 2/4/2009 | US 190 |
| 014-06-0040 | 3.446 | 10.757 | 8 | Rapides | Primary | 5/8/2008 | US 165 |
| 015-03-0020 | 4.21 | 6.21 | 8 | Grant | Primary | 1/8/2008 | US 165 |
| 017-04-0051 | 7.48 | 12.71 | 62 | Tangipahoa | Primary | 10/19/2009 | US 51 |
| 022-05-0050 | 3.814 | 9.955 | 58 | LaSalle | Primary | 6/26/2008 | US 84 |

| Project Number | Begin Log Mile | End Log Mile | District | Parish | Pavement Type | Construction Date | Route |
|---|---|---|---|---|---|---|---|
| 034-05-0031 | 12.859 | 14.138 | 8 | Natchitoches | Primary | 10/17/2008 | LA 6 |
| 052-02-0025 | 0 | 10.84 | 61 | Pointe Coupee | Primary | 11/21/2008 | LA 1 |
| 052-30-0022 | 0 | 7.319 | 8 | Avoyelles | Primary | 12/3/2008 | LA 1 |
| 053-01-0028 | 5.654 | 8.562 | 8 | Rapides | Primary | 10/21/2008 | LA 1 |
| 053-05-0044 | 0.000 | 0.587 | 8 | Natchitoches | Primary | 7/25/2008 | LA 1 |
| 066-08-0012 | 7.535 | 7.843 | 3 | St.Landry | Primary | 1/4/2010 | US 167 |
| 205-03-0016 | 1.377 | 7.77 | 8 | Avoyelles | Secondary | 2/3/2009 | LA 29 |
| 264-03-0019 | 0 | 3.59 | 61 | Ascension | Secondary | 2/13/2008 | LA 74 |
| 450-03-0071-A | 0 | 0.77 | 7 | Jeff Davis | Interstate | 7/31/2009 | I 10 |
| 450-30-0074 | 0.41 | 5.575 | 7 | Calcasieu | Interstate | 5/18/2009 | I 210 |
| 451-02-0048 | 9.817 | 15.66 | 4 | Bossier | Interstate | 9/15/2008 | I 20 |
| 454-01-0080 | 6 | 8.3 | 61 | EBR | Interstate | 11/25/2008 | I-12 |
| 834-06-0011 | 0 | 1.524 | 5 | Morehouse | Farm to Market | 9/16/2008 | LA 830-1 |

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| Project Number | District | Parish | Parish | Begin Log Mile | End Log Mile | Pavement Type | Construction Date | Route |
|---|---|---|---|---|---|---|---|---|
| 455-01-0049 | 3 | 28 | Lafayette | 0 | 8.53 | Interstate | 07/03/2008 | I-49 |
| 008-04-0059 | 3 | 49 | St. Landry | 0.647 | 2.142 | Primary | 6/1/2007 | US 190 |
| 037-04-0016 | 5 | 18 | East Carroll | 0 | 6.944 | Secondary | 08/20/2009 | LA 2 |
| 026-08-0025 | 5 | 42 | Richland | 4.24 | 4.61 | Primary | 07/17/2008 | US 425 |
| 052-05-0049 | 8 | 5 | Avoyelles | 1.924 | 9.581 | Primary | 10/6/2006 | LA 1 |
| 052-30-0022 | 8 | 5 | Avoyelles | 0.000 | 7.319 | Primary | 12/3/2008 | LA 1 |
| 146-01-0025 | 8 | 5 | Avoyelles | 2.020 | 7.856 | Secondary | 10/6/2006 | LA 29 |
| 147-04-0014 | 8 | 5 | Avoyelles | 5.949 | 6.290 | Secondary | Proposed | LA 107 |
| 147-04-0016 | 8 | 5 | Avoyelles | 5.948 | 6.301 | Secondary | 10/6/2006 | LA 107 |
| 805-22-0010 | 8 | 5 | Avoyelles | 4.873 | 5.050 | Secondary | Proposed | LA 362 |
| 805-22-0013 | 8 | 5 | Avoyelles | 4.816 | 5.002 | Farm to Market | 10/6/2006 | LA 362 |
| 009-31-0009 | 8 | 22 | Grant | 0.000 | 5.614 | Farm to Market | 1/7/2008 | LA 492 |
| 455-06-0047 | 8 | 35 | Natchitoches | 44.110 | 51.190 | Interstate | 10/4/2005 | I-49 |
| 029-07-0057 | 8 | 40 | Rapides | 7.190 | 10.640 | Farm to Market | 2/22/2002 | LA 496 |
| 053-02-0033 | 8 | 40 | Rapides | 3.280 | 8.590 | Primary | 10/6/2006 | LA 1 |
| 134-02-0022 | 8 | 58 | Vernon | 0.000 | 0.973 | Secondary | 10/6/2006 | LA 8 |
| 034-06-0045 | 8 | 35 | Natchitoches | 4.349 | 7.571 | Primary | 6/30/2010 | LA 6 |
| 014-06-0040 | 8 | 40 | Rapides | 3.446 | 10.757 | Primary | 05/08/2008 | LA 165 |
| 051-02-0021 | 58 | 21 | Franklin | 0.1 | 8.42 | Primary | 07/24/2006 | LA 17 |
| 026-07-0027 | 58 | 21 | Franklin | 1.35 | 6.81 | Primary | 07/28/2008 | LA 15 |
| 152-02-0010 | 58 | 30 | LaSalle | 0 | 2.213 | Secondary | 09/14/2009 | LA 8 |

| Project Number | District | Parish | Parish | Begin Log Mile | End Log Mile | Pavement Type | Construction Date | Route |
|---|---|---|---|---|---|---|---|---|
| 259-01-0010 | 61 | 19 | East Feliciana | 0 | 13.31 | Secondary | 08/07/2008 | LA 63 |
| 819-03-0006 | 61 | 19 | East Feliciana | 0 | 4.66 | Farm to Market | Proposed | LA 432 |
| 454-03-0066 | 62 | 53 | Tangipahoa | 0 | 6.11 | Interstate | 07/30/2007 | I-12 |
| 454-04-0076 | 62 | 52 | St. Tammany | 0 | 10.13 | Interstate | Under Constr. | I-12 |
| 051-02-0021 | 58 | 21 | Franklin | 0.1 | 8.42 | Primary | 07/24/2006 | LA 17 |
| 026-07-0027 | 58 | 21 | Franklin | 1.35 | 6.81 | Primary | 07/28/2008 | LA 15 |
| 152-02-0010 | 58 | 30 | LaSalle | 0 | 2.213 | Secondary | 09/14/2009 | LA 8 |
| 162-01-0029 | 5 | 34 | Morehouse | 0 | 5.56 | Secondary | 1/15/2009 | LA 138 |
| 163-01-0009 | 5 | 42 | Richland | 0 | 7.32 | Secondary | 1/27/2009 | LA 133 |
| 332-01-0013 | 5 | 62 | W Carroll | 0 | 3.31 | Farm to Market | 1/27/2009 | LA 878 |
| 007-04-0043 | 62 | 48 | St. John | 9.319 | 14.13 | Primary | 9/26/2006 | LA 61 |
| 015-08-0026 | 5 | 37 | Ouachita | 4.218 | 10.061 | Primary | 6/16/2009 | US 165 |
| 071-01-0027 | 5 | 42 | Richland | 0 | 7.11 | Secondary | 7/17/2008 | US 425 |
| 034-03-0024 | 8 | 43 | Sabine | 5.054 | 10.96 | Primary | 10/28/2003 | LA 6 |
| 036-04-0060 | 58 | 21 | Franklin | 1.510 | 7.091 | Secondary | 10/12/2006 | LA 4 |
| 039-04-0059 | 58 | 13 | Catahoula | 0.769 | 8.146 | Secondary | 5/1/2009 | LA 8 |
| 052-30-0022 | 8 | 5 | Avoyelles | 0 | 7.319 | Primary | 12/3/2008 | LA 1 |
| 054-02-0007 | 7 | 2 | Allen | 0 | 7.01 | Primary | 4/28/2008 | LA 26 |
| 152-03-0016 | 58 | 13 | Catahoula | 0 | 5.447 | Secondary | 9/14/2009 | LA 8 |
| 197-04-0016 | 7 | 2 | Allen | 6.15 | 10.13 | Farm to Market | 7/30/2009 | LA 383 |
| 451-04-0049 | 4 | 7 | Bienville | 13.88 | 17.39 | Interstate | 6/30/2005 | I-20 |
| 451-05-0104 | 5 | 31 | Lincoln | 0 | 4.779 | Interstate | 6/30/2005 | I-20 |
| 455-06-0047 | 8 | 35 | Natchitoches | 44.11 | 51.19 | Interstate | 10/4/2009 | I-49 |
| 848-17-0004 | 62 | 48 | St.John | 0 | 1.31 | Farm to Market | 5/20/2009 | LA 3217 |

| Project Number | District | Parish | Parish | Begin Log Mile | End Log Mile | Pavement Type | Construction Date | |
|---|---|---|---|---|---|---|---|---|
| 848-18-0007 | 62 | 48 | St.John | 0 | 0.37 | Farm to Market | 5/20/2009 | LA 3223 |
| 848-19-0006 | 62 | 48 | St.John | 0 | 0.23 | Farm to Market | 5/20/2009 | LA 3224 |

**Asphalt Surface Treatment (Chip Seal)**

| Project Number | District | Parish | Begin Log Mile | End Log Mile | Pavement Type | Traffic | Construction Date | Route |
|---|---|---|---|---|---|---|---|---|
| 057-07-0010 | 3 | Evangline | 0 | 9.32 | Primary | 5,572 | 11/8/1999 | US 167 |
| 066-08-0010 | 3 | St. Landry | 0 | 9.34 | Primary | N/A | 8/2/1994 | US 167 |
| 093-02-0007 | 4 | Bienville | 0.000 | 7.277 | Primary | 367 | 1/13/2006 | LA 501 |
| 002-03-0038 | 5 | Richland | 6.030 | 10.080 | Primary | 2,437 | 12/01/2004 | US 80 |
| 002-03-0039 | 5 | Richland | 10.080 | 12.873 | Primary | 1,774 | 10/12/2004 | US 80 |
| 015-07-0058 | 58 | Caldwell | 3.610 | 9.895 | Primary | 6,000 | 1/30/2008 | US 165 |
| 039-04-0047 | 58 | Catahoula | 8.146 | 12.064 | Secondary | 2,300 | 9/25/2006 | LA 8 |
| 008-02-0029 | 61 | Pointe Coupee | 1.56 | 8.74 | Primary | 15,300 | 11/14/2003 | US 190 |
| 008-03-0050 | 61 | Pointe Coupee | 0 | 11.29 | Primary | 9,900 | 10/3/2000 | US 190 |
| 058-01-0024 | 62 | St. Tammany | 0.000 | 5.100 | Primary | 12,400 | 3/15/2005 | LA 41 |
| 030-02-0028 | 62 | St. Tammany | 2.840 | 4.540 | Primary | 7,400 | 12/21/2007 | LA 21 |
| 261-05-0005 | 62 | St. Tammany | 0.000 | 5.940 | Secondary | 4,500 | 10/12/2005 | LA 22 |
| 047-01-0040 | 62 | Tangipahoa | 0.000 | 2.070 | Secondary | 6,800 | 10/10/2003 | LA 16 |
| 415-02-0013 | 62 | Tangipahoa | 2.740 | 4.000 | Secondary | 7,500 | 2/21/2003 | LA 40 |
| 030-03-0018 | 62 | Washington | 0.000 | 6.800 | Primary | 7,400 | 12/21/2007 | LA 21 |
| 279-04-0022 | 62 | Washington | 13.210 | 15.980 | Secondary | 9,600 | 11/29/2004 | LA 60 |
| 261-04-0019 | 62 | Tangipahoa | 0 | 2.9 | Secondary | 5,487 | 09/01/1998 | LA 22 |
| 055-04-0017 | 3 | Vermilion | 0.000 | 0.830 | Secondary | 2,800 | 10/15/2003 | LA 14 |

| Project Number | District | Parish | Begin Log Mile | End Log Mile | Pavement Type | Traffic | Construction Date | Route |
|---|---|---|---|---|---|---|---|---|
| 016-05-0028 | 05 | Morehouse | 12.254 | 16.144 | | 1,900 | 10/1/2004 | US 165 |
| 020-08-0025 | 05 | East Carroll | 5.340 | 9.826 | | 3,000 | 05/21/2004 | US 65 |
| 023-05-0039 | 08 | Winn | 1.096 | 2.933 | | 10,400 | 11/15/2004 | US 167 |
| 261-04-0021 | 62 | Tangipahoa | 2.286 | 7.910 | | 12,800 | 12/06/2004 | LA 22 |
| 067-08-0014 | 37 | Ouachita | 0.000 | 9.000 | | N/A | 11/12/2003 | LA 34 |
| 015-03-0023 | 08 | Grant | 0.000 | 4.349 | | 9,600 | 09/07/2004 | US 165 |

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| Project Number | District | Begin Log Mile | End Log Mile | Pavement Type | Traffic | Construction Date | Route |
|---|---|---|---|---|---|---|---|
| 001-03-0085 | 4 | 2.1 | 3.542 | Primary | 18,129 | 6/17/2009 | US 80 |
| 067-09-0038 | 5 | 0 | 5.559 | Primary | 13,696 | 4/9/2001 | LA 34 |
| 012-06-0049 | 7 | 4.87 | 12.82 | Primary | 3,300 | 2/14/2008 | US 190 |
| 053-01-0028 | 8 | 5.654 | 8.562 | Primary | 3,060 | 10/21/2008 | LA 1 |
| 261-04-0021 | 62 | 2.286 | 7.91 | Secondary | 14,500 | 12/13/2004 | LA 22 |
| 001-08-0035 | 5 | 0.600 | 1.478 | Primary | 19,400 | 3/22/2004 | US 80 |
| 451-08-0060 | 5 | 0.000 | 5.096 | | N/A | 11/10/2003 | I-20 |