# RELATIONSHIP BETWEEN PAVEMENT MACROTEXTURE AND CRASH INCIDENCES ON NORTH CAROLINA ROADS

Final Report
**FHWA/NC/2007-12**

Submitted to

North Carolina Department of Transportation
Research and Analysis Group
1 South Wilmington Street
Raleigh, NC 27601

By

Srinivas S. Pulugurtha, Ph.D., P.E.
Prasanna R Kusam, M.S., E.I.T.
Kuvleshay Patel, M.S., E.I.T.

Department of Civil & Environmental Engineering
The University of North Carolina at Charlotte
9201 University City Boulevard
Charlotte, NC 28223-0001

February 27, 2008

**Technical Report Documentation Page**

| | | |
|---|---|---|
| 1. FHWA/NC/2007-12 | 2. Government Accession No. | 3. Recipient's Catalog No. |
| 4. Title and Subtitle<br>Relationship between Pavement Macrotexture and Crash Incidences on North Carolina Roads | | 5. Report Date<br>February 27, 2008 |
| | | 6. Performing Organization Code |
| 7. Author(s)<br>Srinivas S Pulugurtha | | 8. Performing Organization Report No. |
| 9. Performing Organization Name and Address<br>Department of Civil & Environmental Engineering<br>The University of North Carolina at Charlotte<br>9201 University City Boulevard<br>Charlotte, NC 28223 – 0001<br>Telephone: 704-687-6660<br>Fax: 704-687-6953<br>Email: sspulugurtha@uncc.edu | | 10. Work Unit No. (TRAIS) |
| | | 11. Contract or Grant No. |
| 12. Sponsoring Agency Name and Address<br>North Carolina Department of Transportation<br>Research and Analysis Group<br>1 South Wilmington Street<br>Raleigh, North Carolina 27601 | | 13. Type of Report and Period Covered<br>Final Report<br>July 1, 2006 – December 31, 2007 |
| | | 14. Sponsoring Agency Code<br>2007 - 12 |
| Supplementary Notes: | | |

16. Abstract

A recent study in Australia has shown that there is a relation between low pavement macrotexture and crash incidences on highways. However, literature documents no such research in the United States. This study focuses on evaluating the role of pavement macrotexture in crashes on selected roads in the state of North Carolina (NC). Pavement macrotexture refers to variations in the road surface in the range 0.02" (0.5 mm) to approximately 2" (50 mm). Laser profilometer data obtained from the NC Department of Transportation (NCDOT) is processed to calculate estimated pavement macrotexture at one-sixteenth of a mile interval according to the ASTM standards. Crash data collected over the same lengths of the corridors were integrated with the calculated pavement macrotexture. Scatter plots, bivariate analysis and multivariate analysis showed that a strong relationship exists between pavement macrotexture and crash incidences on NC roads. Analyses and evaluation indicate that crashes decrease with increase in pavement macrotexture on NC roads. Pavement macrotexture greater than or equal to 0.06" (but typically less than 0.12") would be most appropriate to provide safe and efficient transportation to road users.

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|---|---|---|---|
| 17. Key Words<br>Crashes, safety, pavement, macrotexture, analysis | 18. Distribution Statement | | |
| 19. Security Classif. (of this report)<br>Unclassified | 20. Security Classif. (of this page)<br>Unclassified | 21. No. of Pages<br>75 | 22. Price |

## DISCLAIMER

## ACKNOWLEDGEMENTS

The authors acknowledge the North Carolina Department of Transportation (NCDOT) for providing financial support for this project. The authors thank Judith Corley-Lay, Tony Wyatt, Neil Mastin, Stephen Lowry, Jay Bennett, Neal Galehouse, Brad Hibbs, Scott Capps, J. Kevin Lacy, Mike Venable, Moy Biswas, Robert S. Foyle, Bryan Staley, II, and Ernest Morrison for serving on the project panel and for reviewing the project work. Special thanks are extended to Judith Corley-Lay, Tony Wyatt, Neil Mastin, Stephen Lowry and Jay Bennett for providing required data and valuable inputs for successful completion of the project.

The authors also thank all graduate students in transportation engineering at the University of North Carolina at Charlotte for their help in entering the data into spreadsheets, when needed for this project.

# EXECUTIVE SUMMARY


A recent study in Australia has shown that there is a relation between low pavement macrotexture and crash incidence on highways. However, literature documents no such research in the United States. This study focuses on evaluating the role of pavement macrotexture in crashes on selected roads in the State of North Carolina (NC). Pavement macrotexture refers to variations in the road surface in the range 0.02” (0.5 mm) to approximately 2” (50 mm). Laser profilometer data obtained from the NC Department of Transportation (NCDOT) are processed to calculate estimated pavement macrotexture at one-sixteenth of a mile (0.0625) interval according to the ASTM standards. Crash data collected over the same lengths of the corridors were integrated with the calculated pavement macrotexture.

Scatter plots and bivariate analysis showed that a strong relationship exist between pavement macrotexture and crashes on NC roads. The coefficient for pavement macrotexture is negative indicating that the number of crashes or logarithm of crashes decreases as pavement macrotexture increases. Similar results were observed when analyzed to study the relationship between dry crashes, wet crashes, injury crashes and property damage only crashes with pavement macrotexture. The statistical parameters indicate that the relationship between pavement macrotexture and logarithm of crashes is relatively strong when compared to the relationship between pavement macrotexture and crashes. The relatively low $R^2$ values indicate that pavement macrotexture alone cannot explain the crashes on NC roads.

Predictor variables such as million vehicle miles of travel (as function of traffic volume and length), the number of interchanges, the number of at-grade intersections, the number of grade separated interchanges and the number of bridges, culverts and overhead signs were considered along with pavement macrotexture to study their relationship with crashes. Multivariate analyses were conducted by considering crashes and logarithm of crashes as dependent (target) variable. In all the cases tested, results indicate a relatively strong relationship between pavement macrotexture and logarithm of crashes than pavement macrotexture and crashes.

Analyses and evaluation indicate that crashes decrease with increase in pavement macrotexture on NC roads. Pavement macrotexture greater than or equal to 0.06” but typically less than 0.12” would be most appropriate to provide safe and efficient transportation to road users.

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# CHAPTER 1: INTRODUCTION

North Carolina (NC) on average has seen more than 220,000 reported crashes per year during the last 3 years. More than 35 percent of these reported crashes happened on Interstate routes, United States (US) routes and NC routes (Figure 1). The figure, which is based on 2003 crash data, also indicates that more than 50 percent of fatalities occur on Interstate routes, US routes and NC routes. The North Carolina Department of Transportation (NCDOT), who has jurisdictional responsibility on Interstate routes, US routes, and NC routes as well as a vast majority of secondary roads, is constantly in search of potential solutions to enhance safety and save lives on NC roads. Having a good understanding of the relationship between crashes and their causal factors plays a pivotal role in selecting appropriate countermeasures. Improving safety potentially saves lives, reduces injuries, and has economic impacts while reducing adverse publicity. In turn, this will result in reduced congestion, delays, travel time, vehicle emissions, and energy consumption.

Most State Departments of Transportation (DOTs) obtain data pertaining to reported crashes from the Department of Motor Vehicles (DMV) and maintain a crash database for use in safety analyses and improvement programs. Road conditions, traffic characteristics, driver characteristics/behavior, and temporal variations, in general, have a bearing on safety on roads. Pavement macrotexture is one such road related characteristic when below a threshold value may have an impact on safety on roads. However, not much has been done in the past to determine pavement macrotexture and assertively state that there is a relationship between pavement macrotexture and crash incidence on roads. Thus, there is a need to determine pavement macrotexture and study its relationship with crashes.

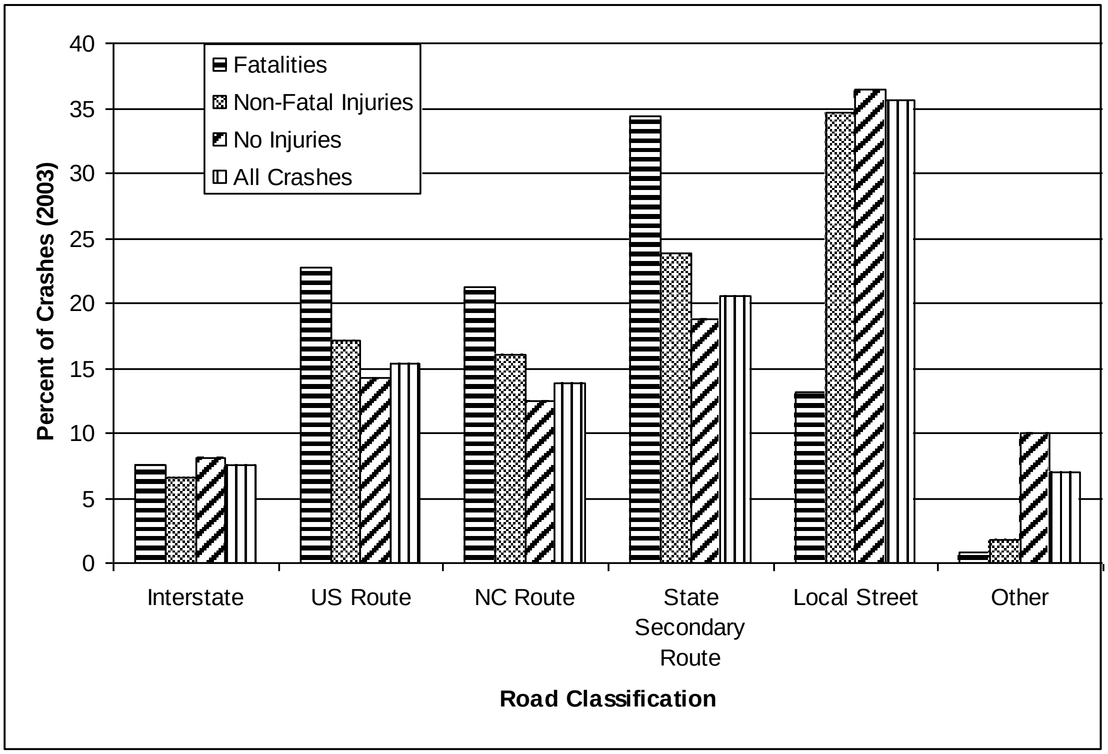



Figure 1. Crashes in North Carolina by Road Classification

Laser profilometers are typically used to collect elevation details of pavement profile to determine a variety of pavement characteristics. NCDOT collects laser profilometer data to measure characteristics such as pavement roughness and rutting on NC roads. However, currently data is not collected exclusively to measure pavement macrotexture, which could also be calculated using profile elevation data from laser profilometers. Thus, recommended procedures based on standards set by American Society for Testing and Materials (ASTM) have to be identified to determine pavement macrotexture using the raw profile elevation data collected from the laser profilometer.

The determined pavement macrotexture data when integrated with crash data and studied using statistical and analytical techniques help understand and establish the relationship between pavement macrotexture and crash incidences on NC roads. Demonstrating and understanding the relationship between the two will help use laser profilometer data to identify pavement sections with low pavement macrotexture values (say, below a threshold value) and proactively apply remedial treatments.

## 1.1 Research Objectives

The objectives of this research are:

1) to understand collected laser profilometer data and develop procedures to measure pavement macrotexture, and,
2) to integrate / tie laser profilometer data and crash data to study the relationship between pavement macrotexture and crash incidences on NC routes.

## 1.2 Organization of the Report

The rest of the report comprises of 5 chapters. A discussion on macrotexture, techniques to measure macrotexture, and past research on relationship between macrotexture and crashes is presented in Chapter 2. The methodology adopted in this study is discussed in Chapter 3. Data collected is discussed in Chapter 4. The calculation of pavement macrotexture for each section of selected corridors is discussed in Chapter 5. Bivariate analysis and multivariate statistical analysis to explain the relationship between pavement macrotexture and crash incidences are discussed in Chapter 6. Conclusions and scope for future research are presented in Chapter 7.

# CHAPTER 2: LITERATURE REVIEW

Cairney and Styles (2005) defined texture as deviations in surface elevation from a fixed datum level, ranking from less than 0.02” (0.5 mm) to approximately 20” (500 mm). Macrotexture refers to variations in the road surface in the range 0.02” (0.5 mm) to approximately 2” (50 mm) (Descornet 1990; Gyenes and Mitchell 1994) whereas variations in the road surface above 2” (50 mm) is referred to as megatexture.

Macrotexture affects braking performance. It is the average depth of the gap between the aggregates in the road surface and assumes a greater role at speeds more than 40 mph (Hill and Henry 1982). It also controls how the friction changes with increasing travel speed (Kennedy et al. 1990) and contributes to noise and rolling resistance of vehicles.

On the other hand, microtexture refers to variations less than 0.02” (0.5 mm) in the road surface and typically predominates at low-speeds (Kennedy et al. 1990) while pavement roughness refers to surface variations larger than megatexture. For wet pavement friction, macrotexture helps provide drainage channels for water to escape thus reducing hydroplaning (a phenomenon of forming a water film on road surface causing loss of traction/friction due to accumulated water between tire pavement interfaces) whereas microtexture breaks the last thin film of water coating to allow aggregate-tire contact (Dewey et al. 2001).

Table 1 summarizes general effects of various texture properties on interactions between vehicles and road such as friction, noise, splash/spray, tire wear and rolling resistance.

Table 1. Effects of Texture Properties on Interactions Between Vehicles and Roads

| Texture | Surface Variations | Effect on Road Vehicle Interactions | | | | | |
|---|---|---|---|---|---|---|---|
| | | Friction | Exterior Noise | Interior Noise | Splash / spray | Tire Wear | Rolling Resistance |
| Microtexture | < 0.02" | X | | | | X | |
| Macrotexture | 0.02" - 2" | X | X | | X | | |
| Megatexture | 2" - 20" | | | X | | | X |
| Roughness | > 20" | | | | | | X |

## 2.1 Measurement of Macrotexture

The measurement of macrotexture can be classified into two categories – static measurement and dynamic measurement. Static measurement is done at specific sites or locations and is considered as traditional and more reliable. It takes more time than dynamic measurement. Volumetric (or sand patch test) method, Outflow meter method and circular track meter (CTM) method are considered as static measurement methods whereas dynamic measurement methods include data collected using laser profilometers. A brief description on volumetric method, CTM method and laser profilometer is presented next.

### *2.1.1 Volumetric Method*

Volumetric (or sand patch test) method is the first and most traditional technique used to measure pavement macrotexture in terms of mean texture depth (MTD) in accordance to “ASTM E965 – Standard Test Method for Measuring Pavement Macrotexture Depth Using a Volumetric Technique (ASTM, 1996)”. This simple to perform method is based on a volumetric test that uses sand, glass beads, or grease that passes a No. 60 sieve but is retained on a No. 80 sieve. The method involves spreading a known volume of sand or glass spheres into a circle on a dry homogenous area without cracks and joints until the surface texture is exposed. The average diameter based on diameter measured at the quarter points is measured and then used to calculate the MTD using the following equation.

$$MTD = \frac{4V}{\pi D^2}$$

where, V is sample volume, $in^3$ ($mm^3$),

D is average diameter of the area covered by the material, in (mm).

### *2.1.2 CTM Method*

The CTM method, in accordance with “ASTM E2157 – Standard Test Method for Measuring Pavement Macrotexture Properties Using the Circular Track Meter (ASTM, 2001)”, has a laser displacement sensor mounted on an arm that rotates in a circular track. It is connected to a notebook computer with software that stores and processes the data to finally give mean profile depth (MPD). The MPD from a CTM is not the same as the MTD calculated in the volumetric (sand patch test) method. The MPD is an indication of the profile of the surface but not the texture. However, MPD measured using CTM in accordance with "ASTM E2157 – Standard Test Method for Measuring Pavement Macrotexture Properties Using the Circular Track Meter" are converted to ETD (equivalent to MTD of volumetric method) using the following equation.

$$\mathrm{ETD} = 0.947\mathrm{MPD} + 0.0027 \text{ (units for MPD and ETD are in)}$$

$$\mathrm{ETD} = 0.947\mathrm{MPD} + 0.069 \text{ (units for MPD and ETD are mm)}$$

Studies conducted by Henry (2000), Abe et al. (2000), and McGhee et al. (2003) in the past have reported a good correlation between MPD measured by the CTM and the MTD measured by the volumetric (sand patch test) method.

### *2.1.3 Laser Profilometers*

A laser profilometer is a dynamic texture measuring technique that can take longitudinal and transverse readings which can be used to determine various road characteristics such as roughness, rutting, grooving, and road profiles all at once with the help of different software programs. The scales of texture are given in terms of wavelength ranges present in the road surface profile. The level of texture is then defined by the amplitude of these wavelengths and is measured in decibels (dB). A digitally stored profile of the surface can be numerically analyzed for its wavelength components. They can survey approximately 300 miles of road per day at intervals as small as 1".

The study by Jackson (2005) showed that speed does not significantly affect the measure of texture. As the readings can be taken accurately at any traffic speeds there is no need for traffic control during the surveys. However, MPD measured using laser profilometers in accordance with "ASTM E1845 – Standard Practice for Calculating Pavement Macrotexture Mean Profile Depth" are not close to MTD measured using volumetric (sand patch test) method. Hence, MPD are converted to ETD (equivalent to MTD of volumetric method) to indicate macrotexture using one of the following equation.

$$\mathrm{ETD} = 0.8\mathrm{MPD} + 0.008 \text{ (units for MPD and ETD are in.)}$$

$$\mathrm{ETD} = 0.8\mathrm{MPD} + 0.2 \text{ (units for MPD and ETD are mm)}$$

## 2.2 Relationship between Pavement Macrotexture and Crash Incidence – Literature Review

A search of journal publications, conference proceedings and the Internet showed only 3 articles on studies related to pavement macrotexture and its relation to crash incidence. These studies are based on research conducted in Great Britain, France, and Australia. The studies in Great Britain (Roe et al., 1991), France (Gothie, 1993), and Australia (Cairney and Styles, 2005) have shown that low macrotexture on pavements is associated with higher crash incidence. However, literature documents no such research on relationship between pavement macrotexture and crash incidences in the United States.

The 1991 study (Roe et al.) in Great Britain looked at the relationship between pavement macrotexture and crashes on three different types of roads (motorways, major roads and minor roads). The sensor measured texture depth (SMTD) values at crash sites are compared with SMTD values for the route as a whole. The number of crash sites with high risk is greater in number when SMTD value was less than 0.8 on one route, less than 0.7 on a second route, and less than 0.6 on a third route indicating increased crash risk with low pavement macrotexture. The study also showed that the number of crash sites increases and is approximately double when SMTD values are below 0.4. In addition, the study have shown that there is no significant difference in the relationship between skidding crashes on a wet pavement, skidding crashes on a dry pavement, non-skidding crashes on a wet pavement, and, non-skidding crashes on a dry pavement and pavement macrotexture suggesting that road condition (dry, wet, etc.) may not have much bearing on crash incidence. Also, the study in Great Britain showed that macrotexture on rural roads had a greater influence on crash frequency at higher speeds. On the other hand, the study showed that microtexture had an influence on low speed skid resistance.

Gothie (1993) studied the relationship between wet-road crashes and macrotexture on national roads (approximately 134 miles or 215 kilometers) in Rhone-Alphes region of France. The study showed that a significant relationship exists between pavement macrotexture below 0.5 mm and wet-road crashes.

The study in Australia looked at data collected along Great Eastern Highway in the State of Western Australia, Princes Highway in the State of Victoria, and Dukes Highway in the State of South Australia (Cairney and Styles, 2005). A laser profilometer was used to measure SMTD. The research team considered a length of 20 meter sections in Western Australia and Victoria whereas lengths of 100 meter sections were considered in South Australia. Data was collected for both directions in Western Australia whereas it was collected for only one direction in Victoria and South Australia. Results from the study, in general, show that crash risk increases as macrotexture falls below a critical value. A significant association was observed between crashes and macrotexture for sections in rural and urban areas along Great Eastern Highway. On Princes Highway West, a significant association was observed between crashes and macrotexture on urban sections whereas a marginally significant association was observed between crashes and macrotexture on rural sections. On Dukes highway, a significant association was observed between crashes and macrotexture on rural sections whereas no association was observed between crashes and macrotexture on urban sections. Variables such as traffic and geometric conditions may be critical but were not considered in the Australia study.

# CHAPTER 3: METHODOLOGY

The methodology to study the relationship between pavement macrotexture and crash incidence on NC routes is divided into 4 steps. They are:

1. Calculating pavement macrotexture for each study section,
2. Identifying the number of crashes in each study section,
3. Integrating data for each study section, and
4. Statistical analysis.

Each of these steps is discussed next in detail.

## 3.1 Calculating Pavement Macrotexture for Each Study Section

Literature review indicates that pavement macrotexture in the past was estimated using volumetric method, CTM, or laser profilometer using appropriate software. NCDOT has collected profile data using Roadware Aran Model 4100 until the fall of 2003. However, since then they have been collecting profile data using ICC Profiler Model MDR 4085. The data collected consists of profile elevation data collected at equal intervals of distance. The Roadware Aran Model 4100 used by NCDOT collects elevation approximately every 8” (0.2 meters). The elevation details are in millimeters. On the other hand, ICC Profiler Model MDR 4085 collects data every 1.242” (0.10349 feet) and the elevation readings are in inches.

The profile data were collected to measure roughness and rutting rather than pavement macrotexture as needed in this study. Hence, a procedure was adopted to determine pavement macrotexture using data collected to measure roughness and rutting in this study. The procedure adopted in this study to measure pavement macrotexture is based on “ASTM E1845 - Standard Practice for Calculating Pavement Macrotexture Mean Profile Depth”.

Each study corridor (example, I-40 eastbound outside lane in Durham County, NC) is divided into one-sixteenth of a mile section of equal length. Each one-sixteenth of a mile section is divided into short segments of a few inches. These short segments are called baseline segments. Each baseline segment is divided into two portions of equal length.

The elevation data are generally collected at intervals smaller than the baseline segment. This elevation data is first processed to identify peak elevations in the two portions of equal length in each baseline segment (Figure 2) so as to determine the mean segment depth of each baseline segment. The above is represented mathematically using the following equation.

$$\text{Mean Segment Depth}_{\text{Baseline}} = \frac{(\text{Peak}_1 + \text{Peak}_2)}{2}$$

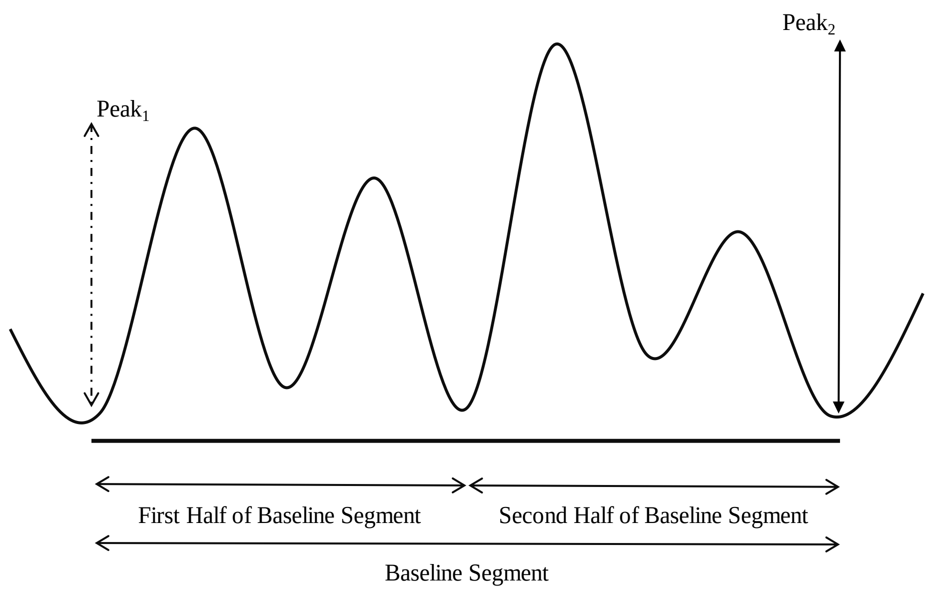



Figure 2. Calculating Mean Profile Depth – An Illustration

The calculated mean segment depth for each baseline segment is then used to determine MPD of each section using the following equation.

$$\text{MPD}_{\text{Section}} = \frac{\sum_1^n \text{Mean Segment Depth}_{\text{Baseline}}}{\text{n}}$$

where, n is the number of baseline segments in each section. As an example, a one-sixteenth of a mile section with a baseline length of 4 inches has $\text{n} = \frac{(330 \times 12)}{4} = 990$ baseline segments.

The length of baseline segment and section may have a bearing on the results obtained. Sensitivity of results with respect to different lengths needs to be investigated.

The estimated MPD for each section could be used directly or converted to ETD using the following equation in accordance with "ASTM E1845 - Standard Practice for Calculating Pavement Macrotexture Mean Profile Depth" to study its relationship with crash incidences.

$$ETD = 0.8MPD + 0.008$$

To adopt the above discussed methodology, the minimum length of baseline segment when analyzing data collected using Roadware Aran Model 4100 is 16" while the baseline segment could be as low as 2.48" when analyzing data collected using ICC Profiler Model MDR 4085. It was felt that data collected at smaller intervals will provide higher level of detail to accurately study the relationship between pavement macrotexture and crash incidences. Thus, data collected using ICC Profiler Model MDR 4085 was only used to study the relationship between pavement macrotexture and crash incidences in this study.

ASTM recommends use of a minimum base length of 100 mm (3.9" or approximately 4") for every 100 meters (3,900" or approximately one-sixteenth of a mile) of test section.

### 3.2 Identifying the Number of Crashes in Each Study Section

In this step, crash data collected for each study corridor are processed to identify the number of crashes on each study section in each direction. The number of crashes for each study section in each direction based on road condition (wet, dry, etc.) and severity (fatal, injury type, and property damage only) are also determined.

Crashes in each section in each direction are identified based on the milepost information for each crash record in the crash database. An MS Excel Spreadsheet application is developed to identify the number of crashes as discussed above using crash data obtained from NCDOT in an MS Excel format.

### 3.3 Integrate Data for Each Study Section

The focus of this step is to integrate pavement macrotexture values and the number of crashes for each study section in order to study the relationship between the two variables. The MS Excel Spreadsheet application developed in the "Identifying the Number of Crashes in Each Study Section" step was enhanced to join pavement macrotexture values for each study section obtained as discussed in the "Estimating Pavement Macrotexture for Each Study Section" step. The resulting summary sheet is then used for further analysis.

### 3.4 Statistical Analysis

Statistical analysis is used to study the statistical significance of relationship between pavement macrotexture and crash incidences on NC routes. Statistical methods that have been widely used include correlation and covariance, simple linear regression, stepwise multiple regression, Chi-Square distribution, and Analysis of Variance (ANOVA). The selection of a method is based on the type of variables (continuous or categorical) and the resulting variables expected to explain the statistical relationship between dependent and independent (or predictor) variables. In general, variables with normal integer and real values are continuous variables whereas binary integer type variables (with values 0 or 1, true or false, etc.) are nominal variables.

Correlation (which is the strength of relation between variables) and covariance are related parameters which measure linear relationship between two variables (continuous or categorical). Linear regression explains the linear relationship between two continuous or categorical variables more explicitly than correlation whereas log-linear regression is aimed to establish a linear regression from a non-linear relation. The major assumption of log-linear regression is that a linear relationship exists between the logarithm of the dependent variable and the independent variables. If there are more than one variable that affect the dependent variable, the dependent variable is tested for relation with more number of independent variables to better represent the relationship. On the other hand, a stepwise multiple regression adds significant variables or eliminates statistically insignificant variables in a stepwise manner from a regression model.

In regression analysis, the assumption is that the residuals are independent and that there is no spatial autocorrelation. Statistical methods such as quadrant analysis and nearest neighbor analysis give correct results for variables with spatial dependence. A Chi-square test can be conducted on any two variables using both quadrant and nearest neighbor analysis methods. The dependent variable is generally a categorical variable.

ANOVA is typically used to determine whether or not a continuous variable is associated with a categorical variable. In this method, a null hypothesis is tested to test the equality of means for a set of sample population by comparing the sample variance estimated from the group means to that estimated within the groups.

As regression analysis can explain the relationship between variables better than ANOVA or other techniques and independent (predictor) variables include both continuous and categorical variables, it was considered more appropriate for this study. Statistical parameters such as level of significance, T-statistic, correlation coefficient, and F-statistic were used to study the model and their goodness of fit.

# CHAPTER 4: STUDY CORRIDORS AND DATA COLLECTION

This chapter presents the selection of study corridors, their details and data obtained from NCDOT to conduct the analysis.

## 4.1 Study Corridors

Six corridors (2 Interstate freeway corridors, 1 US route, and 2 NC routes) with profile data collected using ICC Profiler Model MDR 4085 in the last 4 years were selected to study the relationship between pavement macrotexture and crashes incidences on NC roads. The total length (center-lane miles) is approximately 114 miles for all the selected study corridors. The selected study corridors are listed below.

1. I-40 in Durham County (eastbound and westbound direction; inside and outside lane)
2. I-40 in Pender County (eastbound and westbound direction)
3. US-64 in Martin County (eastbound and westbound direction)
4. NC-42 in Johnston County (eastbound direction)
5. NC-48 in Nash County (northbound direction)

### *4.1.1 I-40 in Durham County*

I-40 in Durham County starts at the border of Orange County and ends at 3 miles upstream of Wake County border line. It is a corridor with two lanes in each direction and 12.81 miles in length. The profile data for both inside lane and outside lane, crash data and roadway features data are collected in the eastbound and westbound directions.

### *4.1.2 I-40 in Pender County*

I-40 in Pender County starts at Duplin County border and ends at New Hanover County line. It is nearly 25.7 miles in length with two lanes in each direction. The profile for outside lane, crash data and roadway features data for this corridor are obtained for both eastbound and westbound directions.

### *4.1.3 US-64 in Martin County*

US-64 in Martin County is a highway with 2 lanes in each direction. The corridor starts at Edgecombe County line and ends at Washington County line. It is 35 miles in length, the largest one of all the corridors considered in the study. The profile data for outside lane, crash data and roadway features data for this corridor are obtained for both eastbound and westbound directions.

### *4.1.4 NC-42 in Johnston County*

NC-42 in Johnston County is a highway extending from Wake County to Wilston County in the eastbound direction. It is a corridor with 2 lanes in each direction and 28.0 miles in length. The profile data for outside lane, crash data and roadway features data are obtained for the eastbound direction.

### *4.1.5 NC-48 in Nash County*

NC-48 in Nash County is a highway from Edgecombe County line to Halifax County line. It is a corridor with 2 lanes in each direction and approximately 15 miles in length. The profile data for outside lane, crash data and roadway features data are obtained from the northbound direction. A summary of number of lanes and length of each selected study corridor is provided in Table 2.

## 4.2 Data

Profile data, crash data from 2002 to 2005, annual average daily traffic (AADT) from 2002 to 2005, and roadway features data were also obtained from NCDOT. The crash data has date of crash, mile post marker reading, direction, severity, light condition, pavement condition, collision type, contributing factor, road characteristics and road class for each crash. The roadway features extracted include number of interchanges, number of bridges, number of culverts, number of grade separated interchanges, number of at-grade intersections, and number of overhead signs. A brief description of each corridor is presented next.

Table 2. Characteristics of Each Selected Study Corridor – Summary

| Corridor | Direction by Lane | # of Lanes | Length |
|---|---|---|---|
| I-40 in Durham | Eastbound - Outside Lane | 3 | 9.89 |
| | Eastbound - Inside Lane | 3 | 9.92 |
| | Westbound - Outside Lane | 3 | 9.74 |
| | Westbound - Inside Lane | 3 | 9.75 |
| I-40 in Pender | Eastbound | 2 | 25.60 |
| | Westbound | 2 | 25.54 |
| US-64 in Martin | Eastbound | 2 | 35.01 |
| | Westbound | 2 | 35.08 |
| NC-42 in Johnston | Eastbound | 1 | 28.01 |
| NC-48 in Nash | Northbound | 1 | 15.16 |

# CHAPTER 5: CALCULATION OF PAVEMENT MACROTEXTURE

The calculation of pavement macrotexture from profile data is presented in this chapter. The variation in calculated ETD between left elevation and right elevation in a lane, between inside lane and outside lane, and the effect of baseline segment length on calculated ETD is also discussed. Data collected for I-40 in Durham County is used to illustrate the working of the methodology.

## 5.1 Calculating Pavement Macrotexture

The raw elevation profile data in ".erd" file format collected using ICC profilometer at 1.242" intervals is used to calculate pavement macrotexture using the procedure discussed in "Calculating Pavement Macrotexture for Each Study Section" subsection in the "Methodology" chapter. As discussed in the methodology, data are grouped into baseline segments to calculate the average elevation of peaks (mean segment depth) based on peak elevation in each equal portion of baseline segment. To facilitate easy splitting of baseline segment into two equal portions and in the calculation of mean segment depth, the number of readings in each baseline segment should be an even number (2 readings, 4 readings, etc.). The calculated mean segment depths are then grouped to calculate the MPD for each section (one-sixteenth mile, one-eighth mile, etc.), which are then converted to ETD for each section. Figure 3 shows ETD by one-sixteenth of a mile (approximately, 100 meters) section using 2.5" (2 readings) as baseline segment for outside lane of I-40 (eastbound direction) in Durham County.

## 5.2 Comparison of ETD Between Left Elevation and Right Elevation

To study the difference in profiles across the lane, ETD was calculated for left and right elevations separately. Figures 3 and 4 show the ETD by one-sixteenth mile section using 2.5" (2 readings) and 5" (4 readings) as baseline segment for outside lane of I-40 (eastbound direction) in Durham County, respectively. Both left elevation and right elevation for outside lane are shown in these figures. The solid line in the figures represents ETD based on right elevation and the dashed line represents ETD based on left elevation.

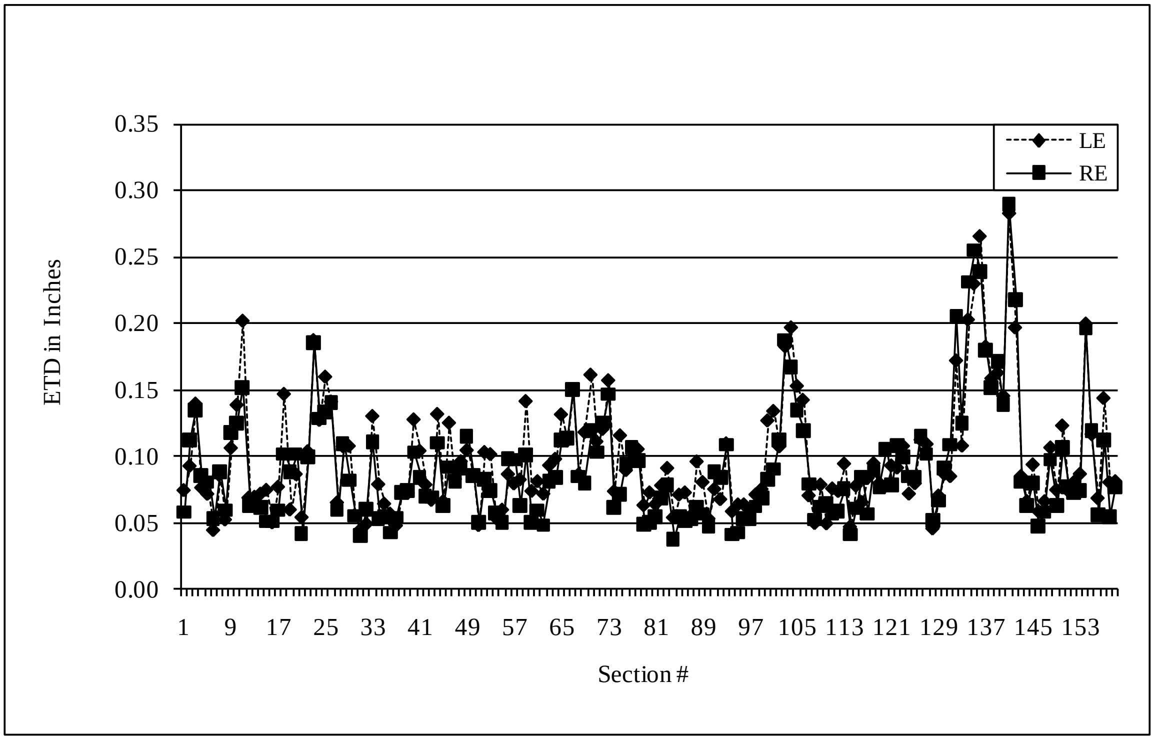



Figure 3. ETD by One-sixteenth Mile Section Using 2.5” Baseline Segment – Outside Lane of I-40 (Eastbound Direction) in Durham County

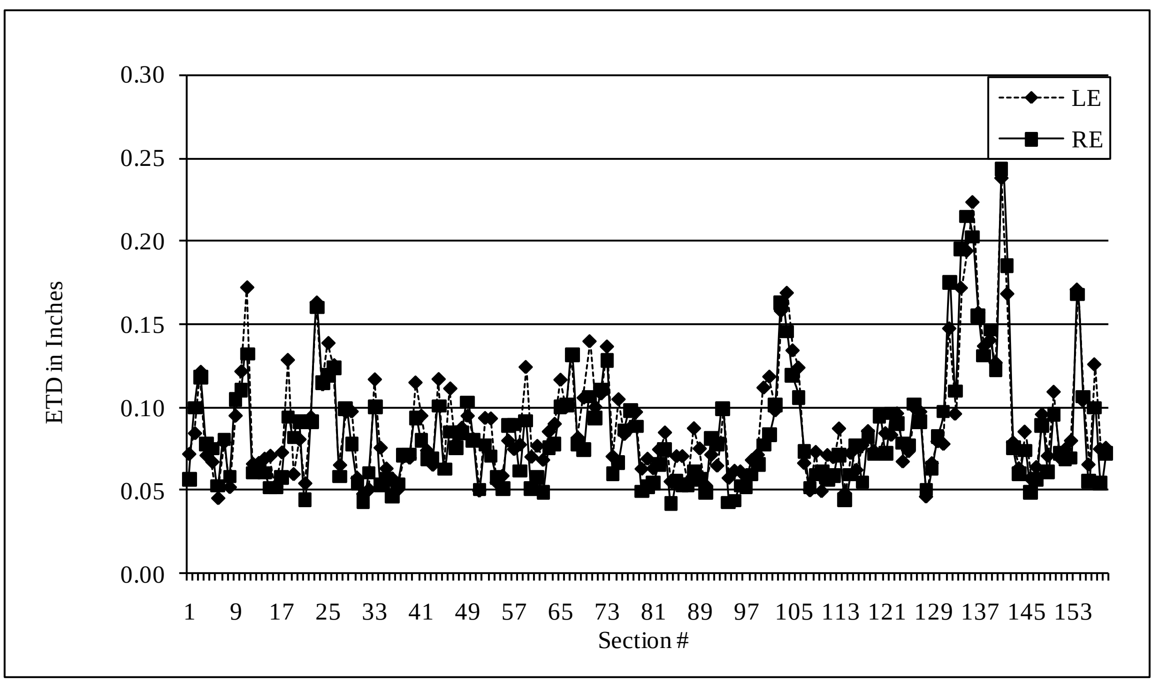



Figure 4. ETD by One-sixteenth Mile Section Using 5” Baseline Segment – Outside Lane of I-40 (Eastbound Direction) in Durham County

It can be seen from the figures that the difference in ETD for left and right elevations is not significant enough to distinguish the lines when looked at a corridor level. A closer look at selected sections within the corridor indicated the same. While this could mean that there is no difference between left elevation and right elevation, it is also possible that the difference in elevation could not be distinguished as the elevation values are very low. Thus, the average of left elevation and right elevation was calculated and used to minimize any possible differences in elevation between left and right elevations.

**5.3 Effect of Baseline Segment Length on ETD**

It was felt that the length of baseline segment should be as small as possible. However, the baseline segment cannot be lower than 2.5” (2 readings) as the procedure involves identifying peaks in each equal portion of baseline segment. The percent difference in average ETD between 2.5” and 5” baseline segments were calculated to study the difference in average ETD between these two baseline segments. It can be seen from Figure 5 that the percent difference for outside lane of I-40 (eastbound direction) in Durham County is generally between 1 percent and 4 percent indicating that ETD using 5” baseline segments are larger in value than 2.5” baseline segments. In general, an increase in percent difference was observed with increase in the length of baseline segment.

A comparison of ETD by section (Figure 3 and Figure 4) shows that fluctuations in ETD based on 2.5” baseline segment is relatively very high when compared to 5” baseline segment. This could be due to 1 reading that has to be considered as peak in each equal portion of baseline segment in case of 2.5” baseline segment. Considering lower value of baseline segment such as 2.5” may ignore variations within a section and may generally result in higher values. On the other hand, smooth profiles can be obtained using longer baseline segments. The problem with using longer baseline segments is that it could result in underestimating the ETD and its effects. Thus, 5” baseline length was felt appropriate for calculation of pavement macrotexture. This is comparable to 4” recommended by ASTM as baseline segment to calculate pavement macrotexture from profile data.

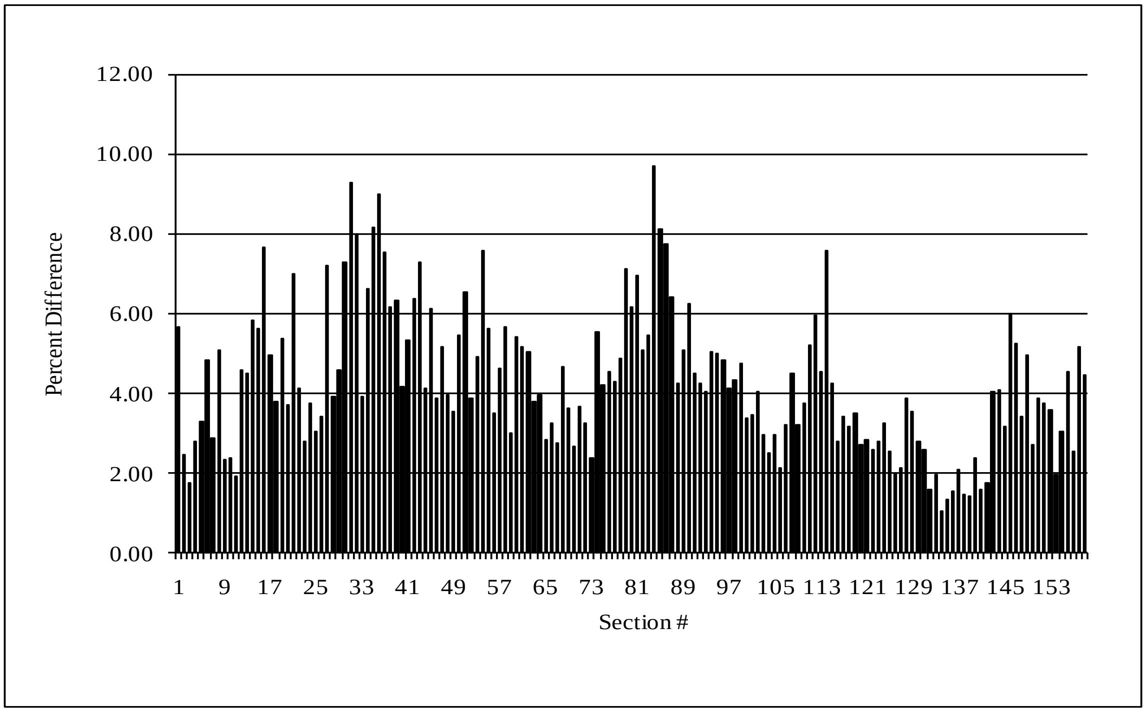



Figure 5. Percent Difference in ETD for One Sixteenth of a Mile Sections between 2.5" and 5"Baseline Segments – Outside Lane of I-40 (Eastbound Direction) in Durham County

**5.4 Effect of Section Length on ETD**

As in the case of baseline segment, the section length should be as small as possible so as to minimize the effects of pavement characteristics, geometric conditions and traffic characteristics on crash incidences on roads. In general, one-sixteenth of a mile and one-eighth of a mile is considered suitable and appropriate for this type of a study. Figure 6 shows ETD by one-eighth of a mile section using 5" baseline segment for outside lane of I-40 (eastbound direction) in Durham County. Comparing ETD from this figure with ETD in Figure 4 (for one-sixteenth of a mile section) indicates no difference in the general trend of ETD over the sections. However, one-sixteenth of a mile tends to yield better estimates of ETD as it accounts for variations in ETD over relatively short distance. In addition, considering one-sixteenth of a mile sections minimizes the effects of variations in pavement, geometric and traffic characteristics on crash incidences. Thus, it was considered for the rest of the analyses in this study.

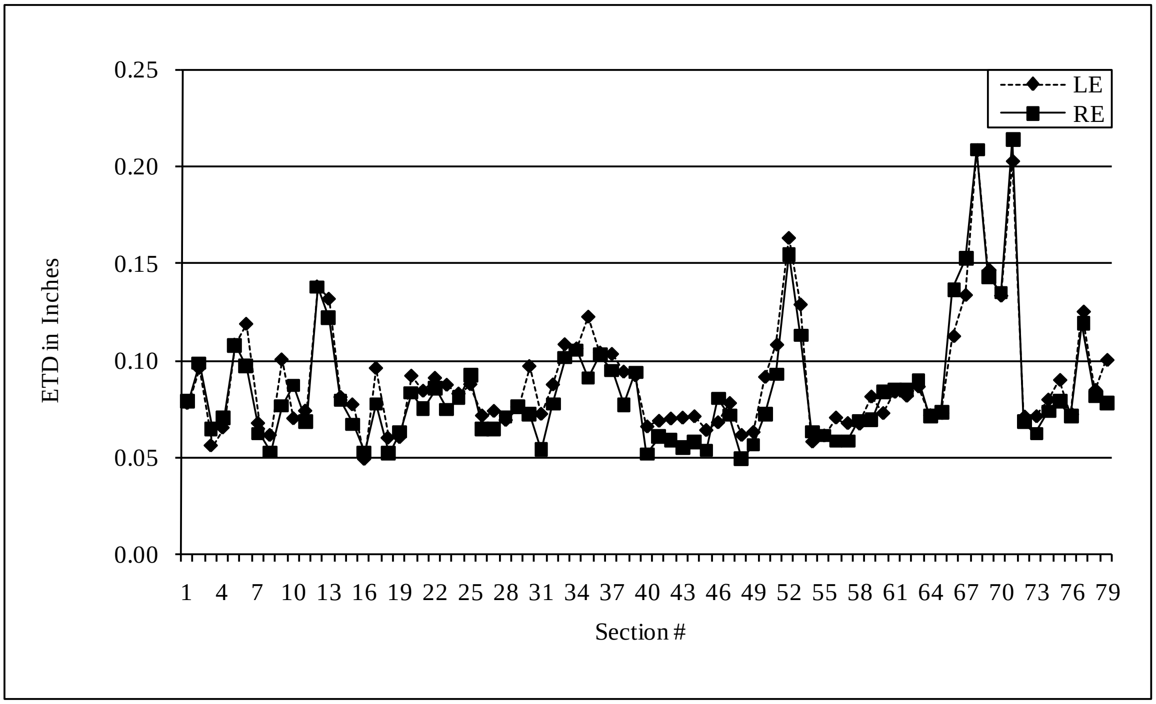



Figure 6. ETD by One-eighth Mile Section Using 5” Baseline Segment – Outside Lane of I-40 (Eastbound Direction) in Durham County

### 5.5 Comparison of ETD between Inside Lane and Outside Lane

Profiles may vary from one lane to another lane in the same travel direction. Figures 7 and 8 shows ETD by one-sixteenth of a mile section using 5” baseline segment and percent difference in ETD between 2.5” and 5” baseline segments for inside lane of I-40 (eastbound direction) in Durham County, respectively. A comparison of data in Figures 4 and 7 shows that the general trends in difference between ETD of left and right elevation is not so significant for these two lanes in the same travel direction. However, calculated pavement macrotexture values for several sections in the same travel direction are lower for outside lane than when compared to the inside lane – possibly due to relatively high truck traffic on outside lane.

The percent difference between pavement macrotexture using 2.5” baseline segment and 5” baseline segment (Figure 8) for inside lane is generally between 2 percent to 3 percent – comparable to the values obtained for outside lane (Figure 5). The percent difference exceeded 4 percent on a few sections on inside lane but was below 7 percent. Overall the percent difference for 5” baseline segments are larger in value than 2.5” baseline segment for inside lane showing similarity with outside lane data.

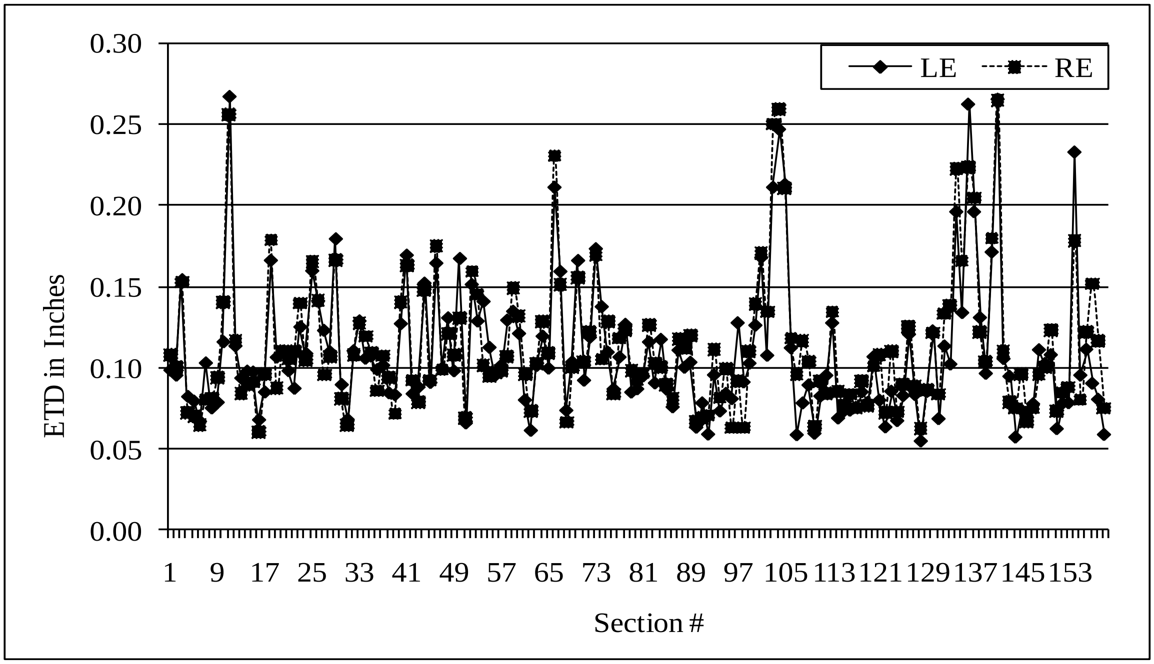



Figure 7. ETD by One-sixteenth Mile Section Using 5" Baseline Segment – Inside Lane of I-40 (Eastbound Direction) in Durham County

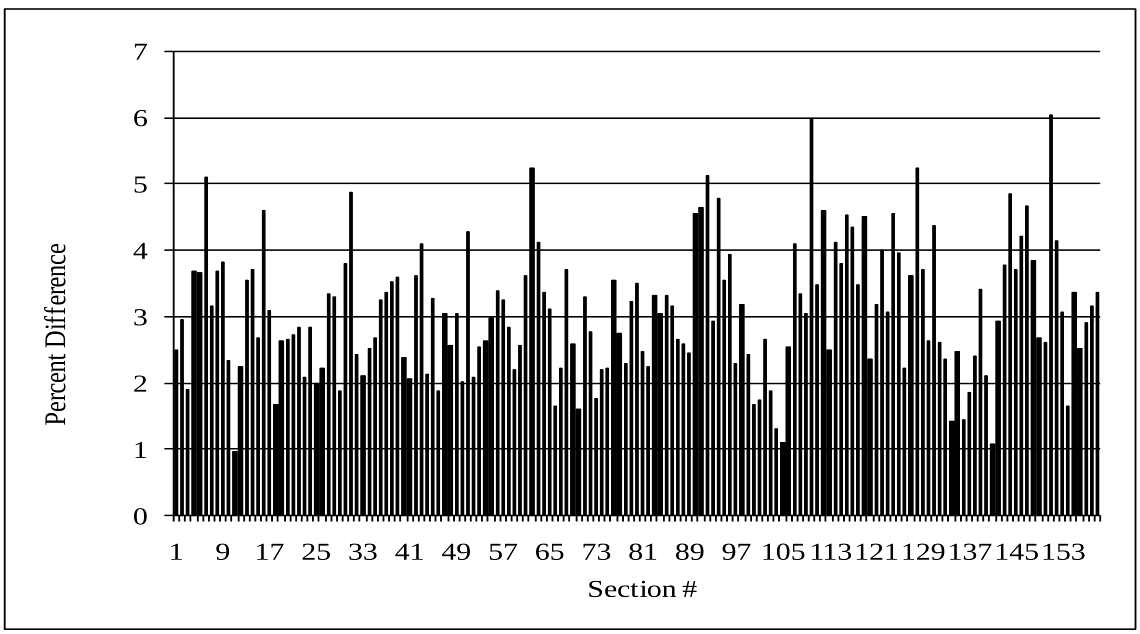



Figure 8. Percent Difference in ETD for One Sixteenth of a Mile Sections between 2.5" and 5" Baseline Segments – Inside Lane of I-40 (Eastbound Direction) in Durham County

**5.6 Comparison of ETD by Travel Direction**

In addition to variation by lane in same travel direction, profiles may also vary by direction of travel. Figures 9 and 10 show ETD by one-sixteenth of a mile section using 5” baseline segment and percent difference in ETD between 2.5” and 5” baseline segments for outside lane of I-40 (westbound direction) in Durham County, respectively. Comparing these figures with Figure 4 and Figure 5 for outside lane of I-40 (eastbound direction) in Durham County indicate that ETD varies by travel direction. Note that section numbers in the figures are by direction and so should be considered from other end to compare ETDs by travel direction for the same mile marker (example, section 1 in case of eastbound direction would be compared to Section 153 in case of westbound direction).

Likewise, Figures 11 and 12 show ETD by one-sixteenth of a mile section using 5” baseline segment and percent difference in ETD between 2.5” and 5” baseline segments for inside lane of I-40 (westbound direction) in Durham County, respectively. Comparing ETD and their percent difference in figures 11 and 12 with figures 7 and 8 indicate variations in values by section (or mile marker location). This could possibly be due to variations in traffic volumes and its composition by direction of travel. However, the general ranges of values remain fairly similar.

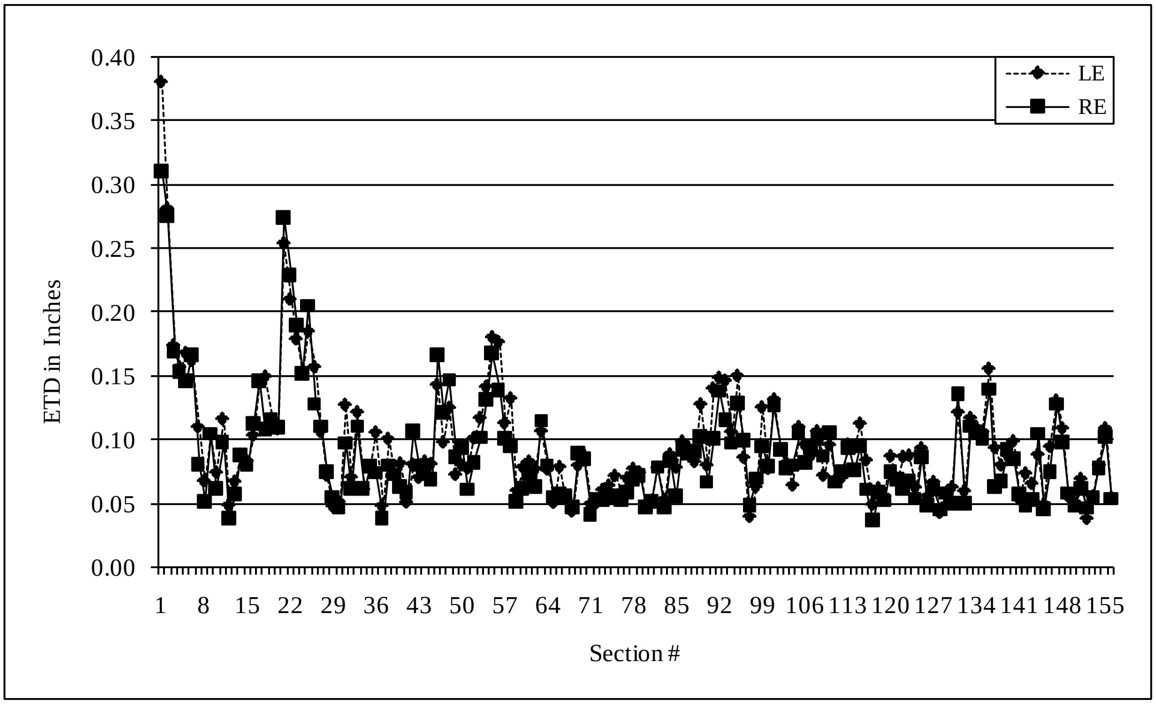



Figure 9. ETD by One-sixteenth of a Mile Section Using 5” Baseline Segment – Outside Lane of I-40 (Westbound Direction) in Durham County

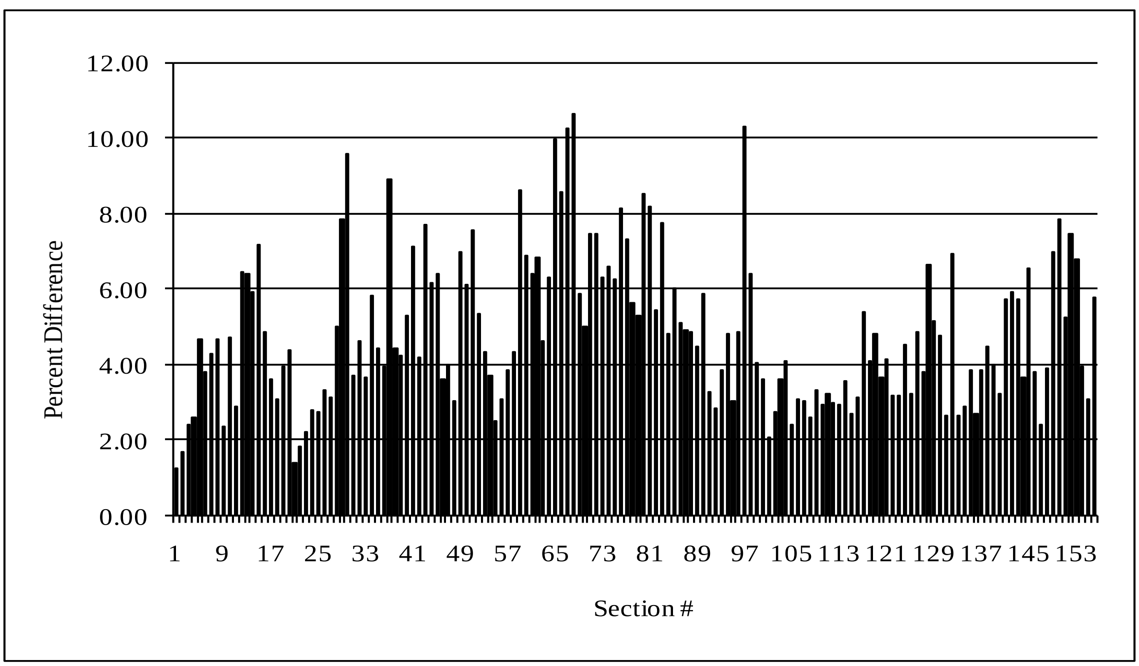



Figure 10. Percent Difference in ETD for One Sixteenth of a Mile Sections between 2.5” and 5” Baseline Segments – Outside Lane of I-40 (Westbound Direction) in Durham County

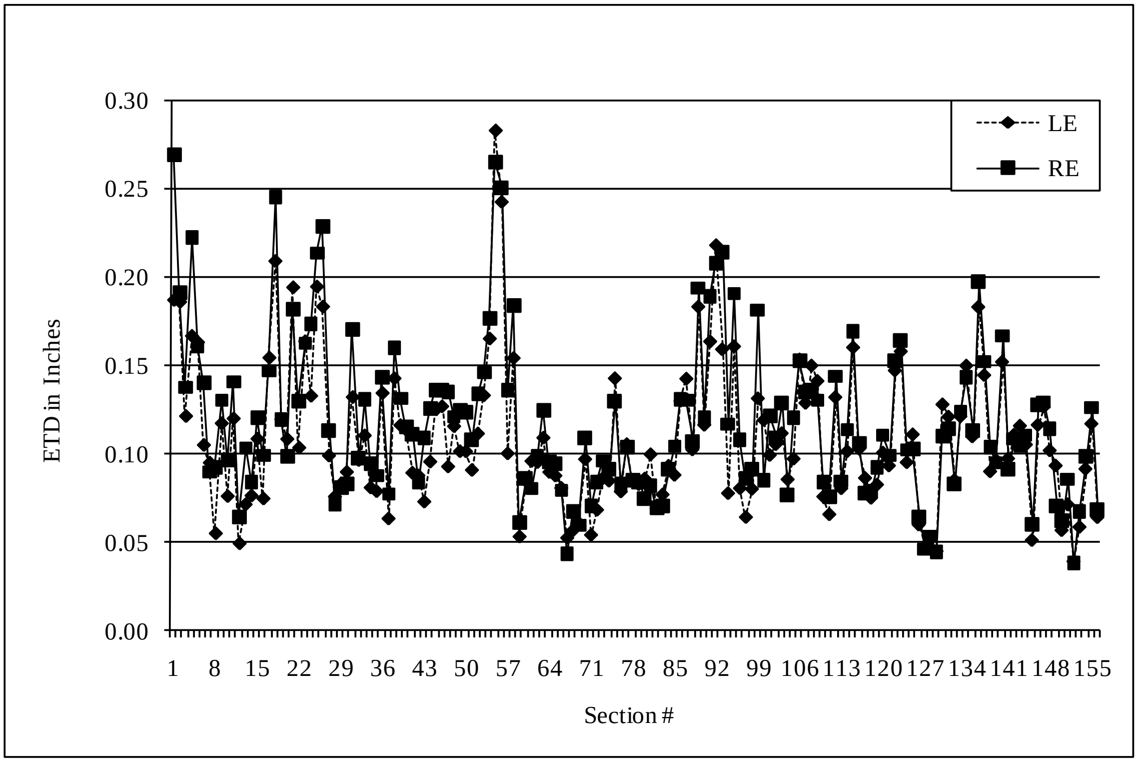



Figure 11. ETD by One-sixteenth of a Mile Section Using 5" Baseline Segment – Inside Lane of I-40 (Westbound Direction) in Durham County

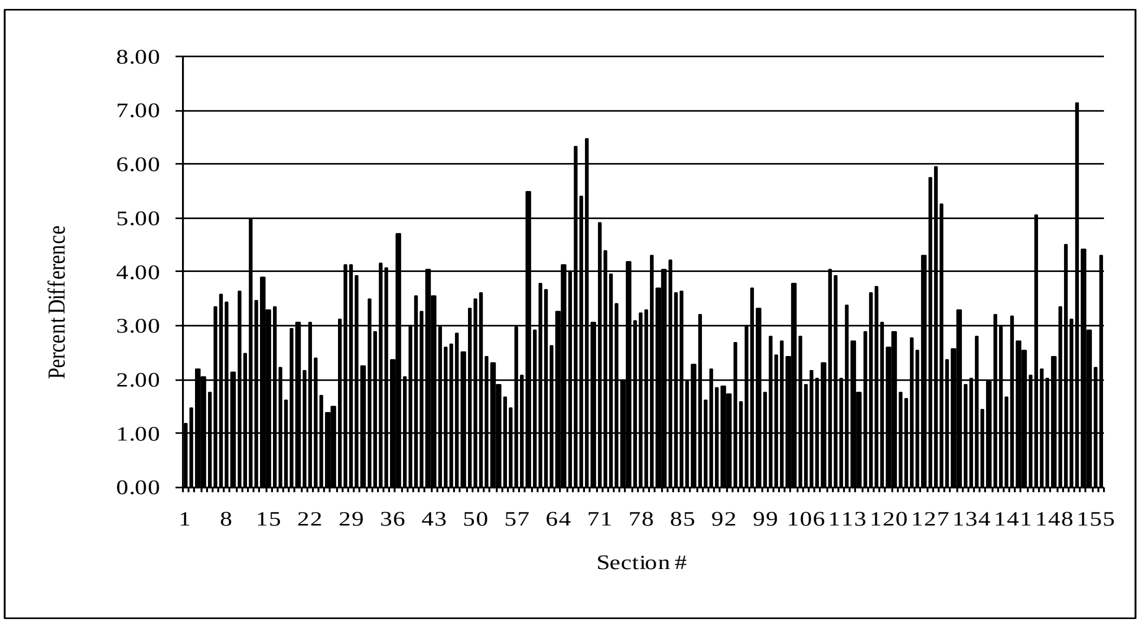



Figure 12. Percent Difference in ETD for One Sixteenth of a Mile Sections between 2.5" and 5" Baseline Segments – Inside Lane of I-40 (Westbound Direction) in Durham County

# CHAPTER 6: STATISTICAL ANALYSIS TO STUDY THE RELATIONSHIP BETWEEN PAVEMENT MACROTEXTURE AND CRASH INCIDENCES

The relationship between pavement macrotexture and crash incidences on selected NC routes is studied using bivariate and multivariate statistical analysis. Results based on these statistical analyses are presented in this chapter. Both linear and log-linear relation was tested in each case. LN in figures and tables represent log-linear relationship.

The calculated ETD values for one-sixteenth of a mile section are grouped into ETD classes and used in statistical analyses. The average of the calculated ETD values is used as a representative value for each ETD class. The million vehicles of mile traveled (MVMT) is calculated using estimated traffic volume per direction and length (one-sixteenth of a mile) of each section. These values are then summed for each ETD class. In addition, roadway features such as number of interchanges, number of bridges, number of culverts, the number of grade separated interchanges, number of at-grade intersections, and number of overhead signs are also summed for each ETD class. Tables showing the above data (ETD, MVMT, number of travel lanes and roadway features) for each class are developed for each study corridor. While 0.005" was used as a range in case of I-40 in Durham County, 0.0025" was used as a range in case of other study corridors. Data in these tables are used for statistical analyses. Classes (outliers) with abnormally high ETD values or number of crashes that could not be clearly explained using variables considered in this study were identified and removed from further analyses. The number of such abnormal classes that were identified and removed varied between 0 and 3.

## 6.1 Bivariate Analyses

Scatter plots were developed to study the role of pavement macrotexture on crash incidences on NC roads. Simple linear regression analysis was conducted to study the linear relation and log-linear relation between pavement macrotexture and crashes for each selected study corridor. A detailed discussion based on results from scatter plots and simple linear regression analysis between pavement macrotexture and crashes is presented in the following subsections. The best fit equation based on simple linear regression analysis is shown in the scatter plots.

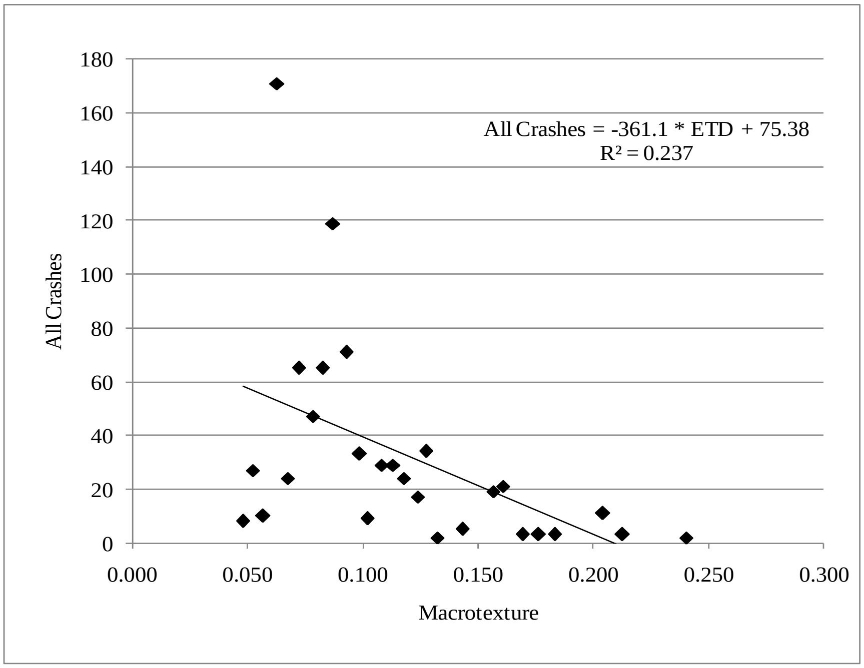
### *6.1.1 I-40 (Eastbound Direction) in Durham County - Outside Lane*

Figure 13 (a) shows the scatter plot between crashes (y-axis) and pavement macrotexture (x-axis) for outside lane on I-40 (eastbound direction) in Durham County. It can be observed from Figure 13(a) that, in general, the number of crashes decreases as pavement macrotexture increases. Likewise, Figure 13(b) shows the scatter plot between logarithm of crashes (y-axis) and pavement macrotexture (x-axis) for the same corridor in Figure 13(a). It can also be seen from Figure 13(b) that the logarithm of crashes decreases as pavement macrotexture increases.

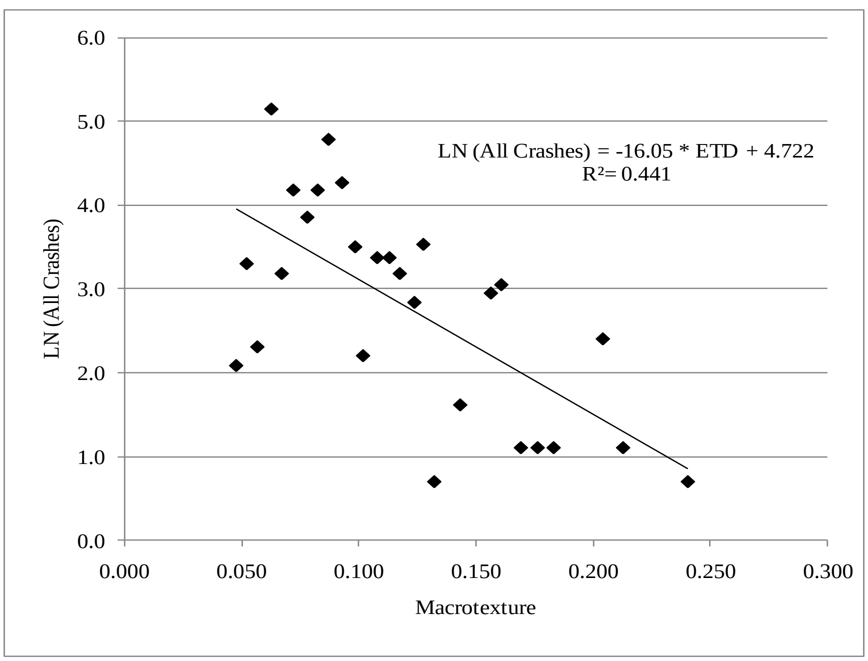
Statistical parameters from linear regression analysis (Table 3) indicate that there is a statistically significant relationship between 1) crashes and pavement macrotexture and 2) logarithm of crashes and pavement macrotexture for this corridor. Similar results were observed when analyzed considering dry crashes, wet crashes, injury crashes and PDO crashes. The coefficient for pavement macrotexture is negative indicating that the number of crashes decreases as pavement macrotexture increases. T-Statistic is greater than 2 and P-Value is always less than 0.05 (95 percent confidence level) for all the crash types except for fatal crashes. The difference between $R^2$ and $R^2$ (Adjusted) is low indicating a good fit. F-Statistic is greater than 4 in all cases except for fatal crashes. A comparison of T-Statistic and P-Value for pavement macrotexture, $R^2$, predicted error in sum of squares (PRESS) and, F-Statistic for crashes and logarithm of crashes shows that a stronger and better relationship exists between logarithm of crashes and pavement macrotexture than when compared to crashes.

### *6.1.2 I-40 (Eastbound Direction) in Durham County - Inside Lane*

Figure 14 (a) shows the scatter plot between crashes (y-axis) and pavement macrotexture (x-axis) for inside lane on I-40 (eastbound direction) in Durham County. It can be observed from Figure 14(a) that, in general, the number of crashes decreases as pavement macrotexture increases. Likewise, Figure 14(b) shows the scatter plot between logarithm of crashes (y-axis) and pavement macrotexture (x-axis) for the same corridor in Figure 14(a). It can also be seen from Figure 14(b) that the logarithm of crashes decreases as pavement macrotexture increases.

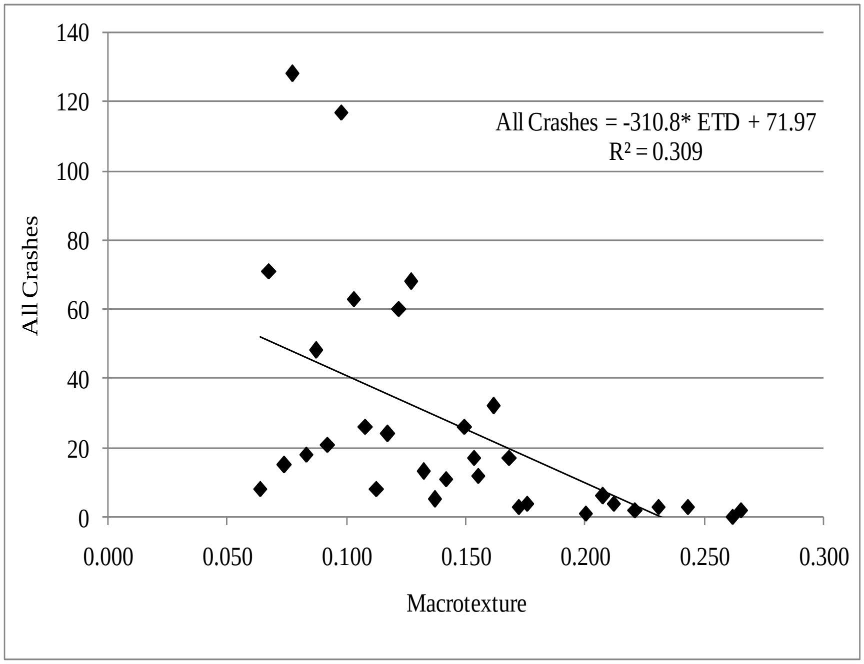



(a) All Crashes and Macrotexture

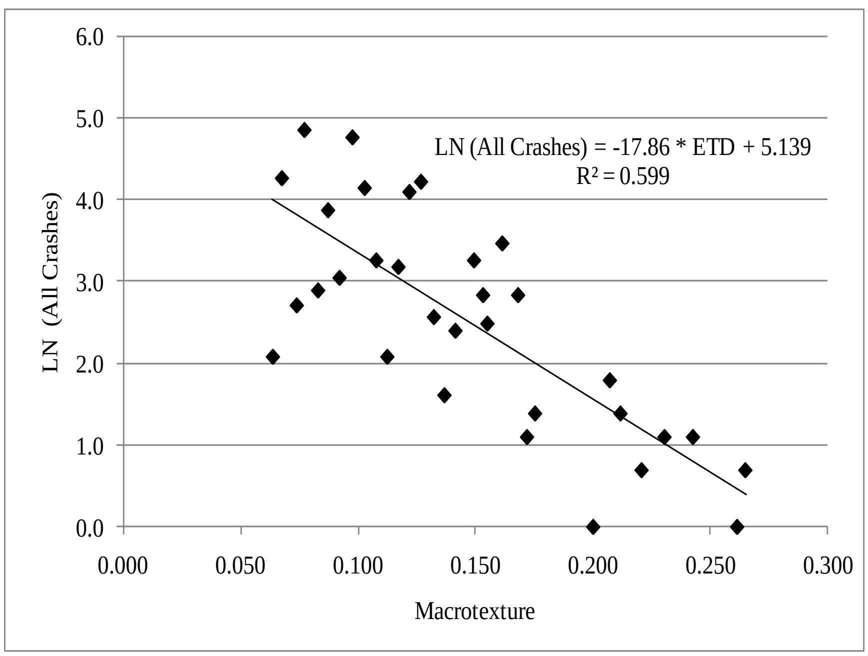



(b) LN (All Crashes) and Macrotexture

Figure 13. Scatter Plots – Outside Lane of I-40 (Eastbound Direction) in Durham County




(a) All Crashes and Macrotexture




(b) LN (All Crashes) and Macrotexture

Figure 14. Scatter Plots – Inside Lane of I-40 (Eastbound Direction) in Durham County

Table 3. Summary of Statistical Parameters from Bivariate Analysis – Outside Lane of I-40 (Eastbound Direction) in Durham County

| Parameters | Crashes Vs. Macrotexture | | | | | | LN of Crashes Vs. Macrotexture | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | All | Dry | Wet | Fatal | Injury | PDO | All | Dry | Wet | Fatal | Injury | PDO |
| Constant | 75.38 | 56.91 | 14.67 | 0.34 | 16.96 | 56.36 | 4.72 | 4.53 | 2.56 | | 3.04 | 4.46 |
| Coefficient | -361.1 | -270.1 | -74.9 | -1.9 | -81.0 | -268.9 | -16.1 | -16.9 | -12.2 | | -13.5 | -16.4 |
| T-Statistic | -2.79 | -2.91 | -2.41 | -1.63 | -2.87 | -2.72 | -4.45 | -4.32 | -3.61 | | -4.12 | -4.36 |
| P-Value | 0.010 | 0.007 | 0.024 | 0.116 | 0.008 | 0.012 | 0.000 | 0.000 | 0.001 | | 0.000 | 0.000 |
| $R^2$ | 23.70 | 25.30 | 18.80 | 9.60 | 24.80 | 22.90 | 44.20 | 42.80 | 34.30 | | 40.40 | 43.20 |
| $R^2$ (Adj.) | 20.60 | 22.30 | 15.60 | 6.00 | 21.80 | 19.80 | 41.90 | 40.50 | 31.70 | | 38.00 | 40.90 |
| PRESS Value | 35475 | 18116 | 2071 | 3 | 1693 | 20517 | 27 | 32 | 24 | | 23 | 29 |
| F-Statistic | 7.77 | 8.47 | 5.79 | 2.65 | 8.23 | 7.42 | 19.77 | 18.69 | 13.05 | | 16.96 | 19.02 |

Statistical parameters from linear regression analysis (Table 4) indicate that there is a statistically significant relationship between 1) crashes and pavement macrotexture and 2) logarithm of crashes and pavement macrotexture for this corridor. Similar results were observed when analyzed considering dry crashes, wet crashes, injury crashes and PDO crashes. The coefficient for pavement macrotexture is negative indicating that the number of crashes decreases as pavement macrotexture increases. T-Statistic is greater than 2 and P-Value is always less than 0.05 (95 percent confidence level) for all the crash types except for fatal crashes. The difference between $R^2$ and $R^2$ (Adjusted) is low indicating a good fit. F-Statistic is greater than 4 in all cases except for fatal crashes. A comparison of T-Statistic and P-Value for pavement macrotexture, $R^2$, PRESS and F-Statistic for crashes and logarithm of crashes, shows that, a stronger and better relationship exists between logarithm of crashes and pavement macrotexture than when compared to crashes.

### *6.1.3 I-40 (Westbound Direction) in Durham County - Outside Lane*

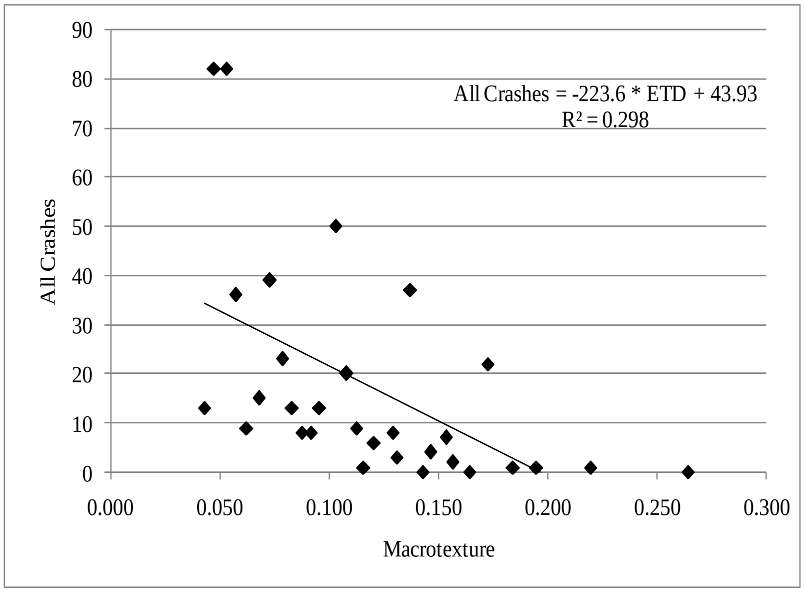
Figure 15 (a) shows the scatter plot between crashes (y-axis) and pavement macrotexture (x-axis) for outside lane on I-40 (westbound direction) in Durham County. It can be observed from Figure 15(a) that, in general, the number of crashes decreases as pavement macrotexture increases.

Table 4. Summary of Statistical Parameters from Bivariate Analysis –
Inside Lane of I-40 (Eastbound Direction) in Durham County

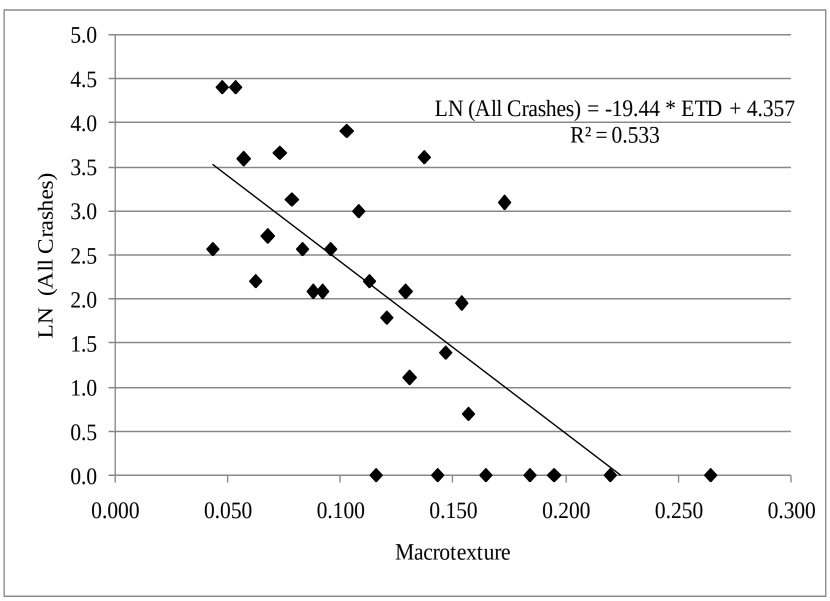
| Parameters | Crashes Vs. Macrotexture | | | | | | LN of Crashes Vs. Macrotexture | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | All | Dry | Wet | Fatal | Injury | PDO | All | Dry | Wet | Fatal | Injury | PDO |
| Constant | 71.970 | 54.361 | 13.828 | 0.325 | 15.702 | 54.500 | 5.138 | 4.836 | 2.524 | 0.080 | 3.093 | 4.779 |
| Coefficient | -310.8 | -233.2 | -62.0 | -1.6 | -66.4 | -236.6 | -17.9 | -17.4 | -11.0 | -0.4 | -12.7 | -17.6 |
| T-Statistic | -3.66 | -3.80 | -2.92 | -1.32 | -3.72 | -3.49 | -6.71 | -6.53 | -4.13 | -1.05 | -4.93 | -6.14 |
| P-Value | 0.001 | 0.001 | 0.007 | 0.197 | 0.001 | 0.002 | 0.000 | 0.000 | 0.000 | 0.301 | 0.000 | 0.000 |
| $R^2$ | 30.90 | 32.50 | 22.10 | 5.50 | 31.60 | 28.90 | 60.00 | 58.70 | 36.30 | 3.60 | 44.70 | 55.70 |
| $R^2$ (Adj.) | 28.60 | 30.30 | 19.50 | 2.30 | 29.30 | 26.50 | 58.70 | 57.30 | 34.10 | 0.30 | 42.90 | 54.20 |
| PRESS Value | 26112 | 13647 | 1625 | 5 | 1141 | 16735 | 25 | 25 | 26 | 1 | 23 | 30 |
| F-Statistic | 13.42 | 14.46 | 8.50 | 1.74 | 13.83 | 12.19 | 44.98 | 42.59 | 17.07 | 1.11 | 24.27 | 37.71 |

Likewise, Figure 15(b) shows the scatter plot between logarithm of crashes (y-axis) and pavement macrotexture (x-axis) for the same corridor in Figure 15(a). It can also be seen from Figure 15(b) that the logarithm of crashes decreases as pavement macrotexture increases.

Statistical parameters from linear regression analysis (Table 5) indicate that there is a statistically significant relationship between 1) crashes and pavement macrotexture and 2) logarithm of crashes and pavement macrotexture for this corridor. Similar results were observed when analyzed considering dry crashes, wet crashes, injury crashes and PDO crashes. As there are no fatal crashes on this corridor in westbound direction, no results were obtained in case of fatal crashes. The coefficient for pavement macrotexture is negative indicating that the number of crashes decreases as pavement macrotexture increases. T-Statistic is greater than 2 and P-Value is less than 0.05 (95 percent confidence level) for all the crash types except for fatal crashes and in case of relation between logarithm of wet crashes and pavement macrotexture. The difference between $R^2$ and $R^2$ (Adjusted) is low indicating a good fit. F-Statistic is greater than 4 in all cases except for fatal crashes and logarithm of wet crashes and pavement macrotexture. A comparison of T-Statistic and P-Value for pavement macrotexture, $R^2$, PRESS and F-Statistic for crashes and logarithm of crashes, shows that, a stronger and better relationship exists between logarithm of crashes and pavement macrotexture than when compared to crashes.




(a) All Crashes and Macrotexture




(b) LN (All Crashes) and Macrotexture

Figure 15. Scatter Plots –Outside Lane of I-40 (Westbound Direction) in Durham County

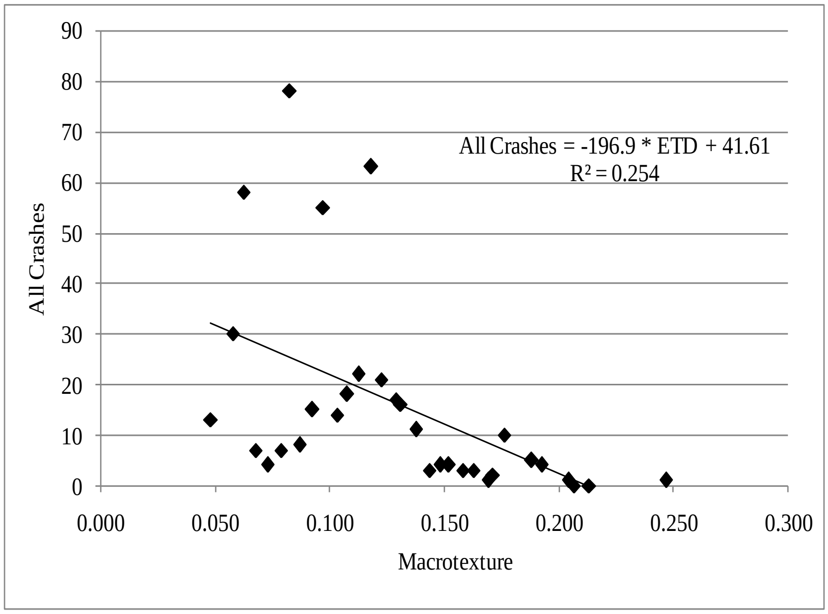
Table 5. Summary of Statistical Parameters from Bivariate Analysis – Outside Lane of I-40 (Westbound Direction) in Durham County

| Parameters | Crashes Vs. Macrotexture | | | | | | LN of Crashes Vs. Macrotexture | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | All | Dry | Wet | Fatal | Injury | PDO | All | Dry | Wet | Fatal | Injury | PDO |
| **Constant** | 43.93 | 37.28 | 4.56 | | 9.29 | 33.20 | 4.36 | 4.12 | 1.02 | | 2.12 | 3.96 |
| **Coefficient** | -223.7 | -190.5 | -22.4 | | -48.0 | -169.2 | -19.4 | -18.9 | -4.6 | | -10.8 | -18.0 |
| **T-Statistic** | -3.45 | -3.46 | -2.57 | | -3.46 | -3.42 | -5.65 | -5.49 | -1.92 | | -4.12 | -5.34 |
| **P-Value** | 0.002 | 0.002 | 0.016 | | 0.002 | 0.002 | 0.000 | 0.000 | 0.065 | | 0.000 | 0.000 |
| **$R^2$** | 29.80 | 29.90 | 19.10 | | 29.90 | 29.50 | 53.30 | 51.80 | 11.70 | | 37.70 | 50.40 |
| **$R^2$ (Adj.)** | 27.30 | 27.40 | 16.20 | | 27.40 | 27.00 | 51.60 | 50.10 | 8.50 | | 35.50 | 48.60 |
| **PRESS Value** | 11611 | 8340 | 208 | | 537 | 67.36.77 | 31 | 31 | 16 | | 19 | 30 |
| **F-Statistic** | 11.89 | 11.96 | 6.62 | | 11.96 | 11.72 | 31.96 | 30.13 | 3.70 | | 16.96 | 28.47 |

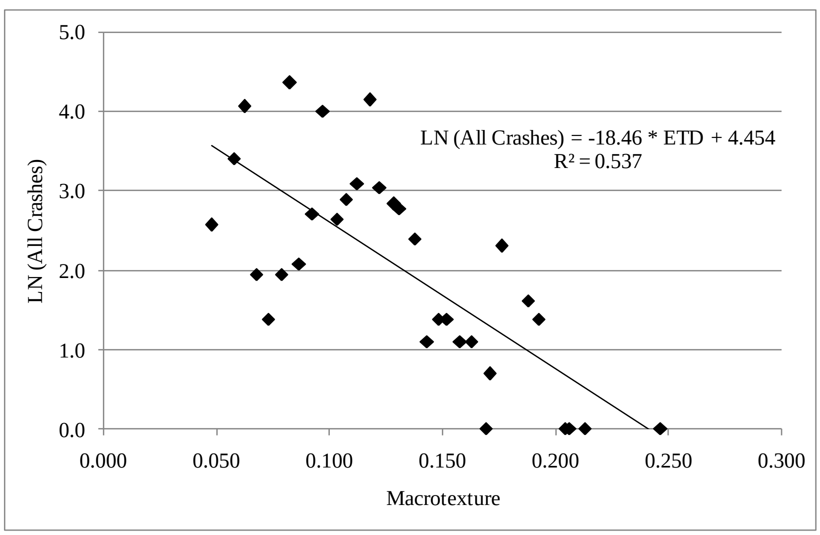
### *6.1.4 I-40 (Westbound Direction) in Durham County - Inside Lane*

Figure 16 (a) shows the scatter plot between crashes (y-axis) and pavement macrotexture (x-axis) for inside lane on I-40 (westbound direction) in Durham County. It can be observed from Figure 16(a) that, in general, the number of crashes decreases as pavement macrotexture increases. Likewise, Figure 16(b) shows the scatter plot between logarithm of crashes (y-axis) and pavement macrotexture (x-axis) for the same corridor in Figure 16(a). It can also be seen from Figure 16(b) that the logarithm of crashes decreases as pavement macrotexture increases.

Statistical parameters from linear regression analysis (Table 6) indicate that there is a statistically significant relationship between 1) crashes and pavement macrotexture and 2) logarithm of crashes and pavement macrotexture for this corridor. Similar results were observed when analyzed considering dry crashes, wet crashes, injury crashes and PDO crashes. As there are no fatal crashes on this corridor in westbound direction, no results were obtained in case of fatal crashes. The coefficient for pavement macrotexture is negative indicating that the number of crashes decreases as pavement macrotexture increases. T-Statistic is greater than 2 and P-Value is less than 0.05 (95 percent confidence level) for all the crash types except for fatal crashes. The difference between $R^2$ and $R^2$ (Adjusted) is low indicating a good fit. F-Statistic is greater than 4 in all cases except for fatal crashes. A comparison of T-Statistic and P-Value for pavement macrotexture, $R^2$, PRESS and F-Statistic for crashes and logarithm of crashes, shows that, a stronger and better relationship exists between logarithm of crashes and pavement macrotexture than when compared to crashes.




(a) All Crashes and Macrotexture




(b) LN (All Crashes) and Macrotexture

Figure 16. Scatter Plots – Inside Lane of I-40 (Westbound Direction) in Durham County

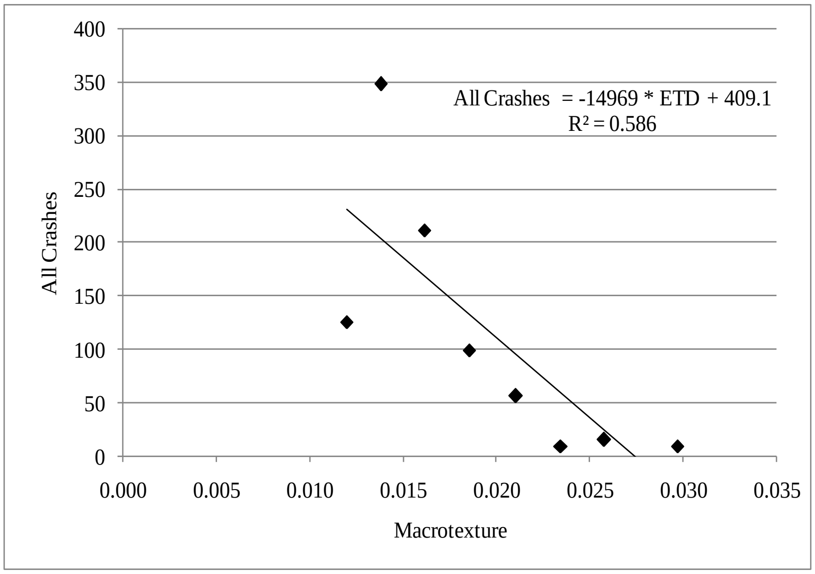
Table 6. Summary of Statistical Parameters from Bivariate Analysis – Inside Lane of I-40 (Westbound Direction) in Durham County

| Parameters | Crashes Vs. Macrotexture | | | | | | LN of Crashes Vs. Macrotexture | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | All | Dry | Wet | Fatal | Injury | PDO | All | Dry | Wet | Fatal | Injury | PDO |
| Constant | 41.62 | 35.41 | 4.15 | | 8.88 | 31.67 | 4.45 | 4.23 | 1.13 | | 2.18 | 4.00 |
| Coefficient | -196.9 | -168.6 | -18.2 | | -43.0 | -150.8 | -18.5 | -18.3 | -5.2 | | -10.5 | -17.5 |
| T-Statistic | -3.20 | -3.13 | -2.44 | | -3.86 | -3.00 | -5.91 | -5.63 | -2.39 | | -4.06 | -5.24 |
| P-Value | 0.003 | 0.004 | 0.021 | | 0.001 | 0.005 | 0.000 | 0.000 | 0.023 | | 0.000 | 0.000 |
| $R^2$ | 25.50 | 24.60 | 16.50 | | 33.20 | 23.00 | 53.80 | 51.30 | 16.00 | | 35.50 | 47.80 |
| $R^2$ (Adj.) | 23.00 | 22.10 | 13.70 | | 30.90 | 20.50 | 52.30 | 49.70 | 13.20 | | 33.30 | 46.10 |
| PRESS Value | 10553 | 8070 | 158 | | 346 | 7086 | 27 | 29 | 13 | | 19 | 31 |
| F-Statistic | 10.26 | 9.80 | 5.93 | | 14.89 | 8.97 | 34.93 | 31.65 | 5.73 | | 16.48 | 27.49 |

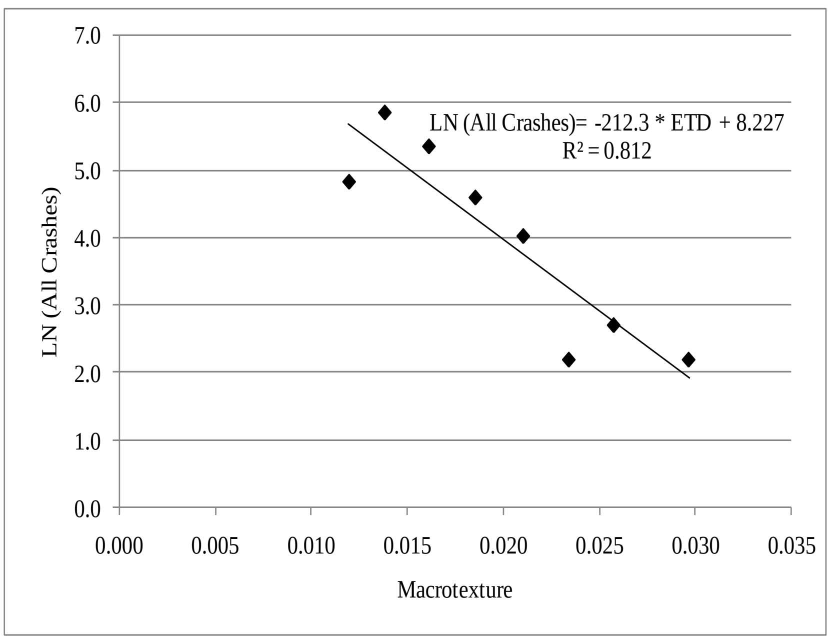
### *6.1.5 I-40 (Eastbound Direction) in Pender County*

Figure 17 (a) shows the scatter plot between crashes (y-axis) and pavement macrotexture (x-axis) for outside lane on I-40 (eastbound direction) in Pender County. It can be observed from Figure 17(a) that, in general, the number of crashes decreases as pavement macrotexture increases. Likewise, Figure 17(b) shows the scatter plot between logarithm of crashes (y-axis) and pavement macrotexture (x-axis) for the same corridor in Figure 17(a). It can also be seen from Figure 17(b) that the logarithm of crashes decreases as pavement macrotexture increases.

Statistical parameters from linear regression analysis (Table 7) indicate that there is a statistically significant relationship between 1) crashes and pavement macrotexture and 2) logarithm of crashes and pavement macrotexture for this corridor. Similar results were observed when analyzed considering dry crashes, wet crashes, injury crashes and PDO crashes. The coefficient for pavement macrotexture is negative indicating that the number of crashes decreases as pavement macrotexture increases. T-Statistic is greater than 2 and P-Value is less than 0.05 (95 percent confidence level) for all the crash types except for fatal crashes. The difference between $R^2$ and $R^2$ (Adjusted) is reasonably low indicating a good fit. F-Statistic is greater than 4 in all cases except for fatal crashes. A comparison of T-Statistic and P-Value for pavement macrotexture, $R^2$, PRESS and F-Statistic for crashes and logarithm of crashes, shows that, a stronger and better relationship exists between logarithm of crashes and pavement macrotexture than when compared to crashes.




(a) All Crashes and Macrotexture




(b) LN (All Crashes) and Macrotexture

Figure 17. Scatter Plots – I-40 (Eastbound Direction) in Pender County

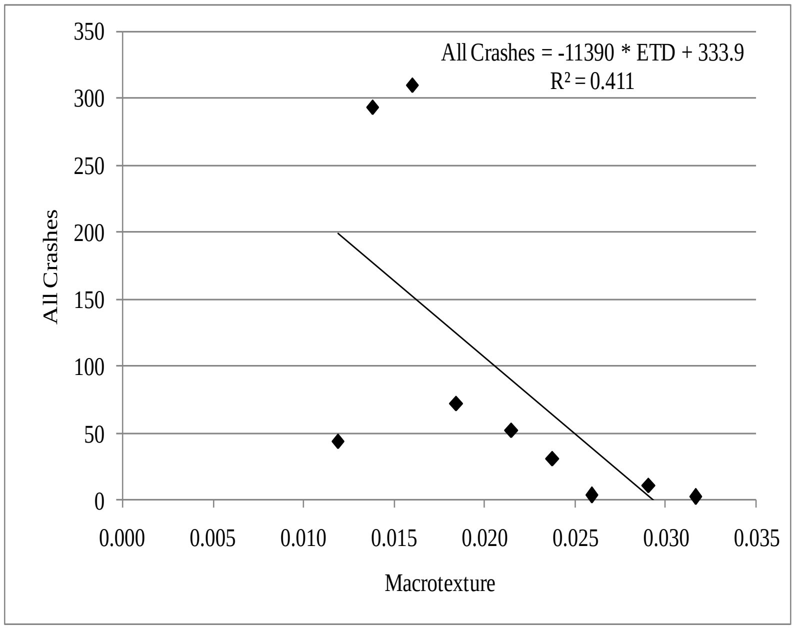
Table 7. Summary of Statistical Parameters from Bivariate Analysis – I-40 (Eastbound Direction) in Pender County

| Parameters | Crashes Vs. Macrotexture | | | | | | LN of Crashes Vs. Macrotexture | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | All | Dry | Wet | Fatal | Injury | PDO | All | Dry | Wet | Fatal | Injury | PDO |
| **Constant** | 409.20 | 310.15 | 84.82 | 2.35 | 95.27 | 303.61 | 8.23 | 8.01 | 7.37 | 0.81 | 6.54 | 8.00 |
| **Coefficient** | -14969 | -11303 | -3189 | -92 | -3492 | -11089 | -212.2 | -217.4 | -257.9 | -31.9 | -201.4 | -215.8 |
| **T-Statistic** | -2.92 | -2.58 | -4.43 | -1.88 | -2.82 | -2.88 | -5.10 | -4.64 | -8.33 | -1.88 | -3.56 | -5.42 |
| **P-Value** | 0.027 | 0.042 | 0.004 | 0.109 | 0.030 | 0.028 | 0.002 | 0.004 | 0.000 | 0.109 | 0.012 | 0.002 |
| **$R^2$** | 58.70 | 52.70 | 76.60 | 37.10 | 56.90 | 58.00 | 81.30 | 78.20 | 92.00 | 37.10 | 67.80 | 83.10 |
| **$R^2$ (Adj.)** | 51.80 | 44.80 | 72.70 | 26.60 | 49.80 | 51.00 | 78.20 | 74.60 | 90.70 | 26.60 | 62.50 | 80.20 |
| **PRESS Value** | 85934 | 62717 | 1652 | 7 | 4985 | 48459 | 5 | 6 | 3 | 1 | 9 | 5 |
| **F-Statistic** | 8.52 | 6.67 | 19.66 | 3.53 | 7.93 | 8.29 | 26.04 | 21.55 | 69.47 | 3.53 | 12.65 | 29.40 |

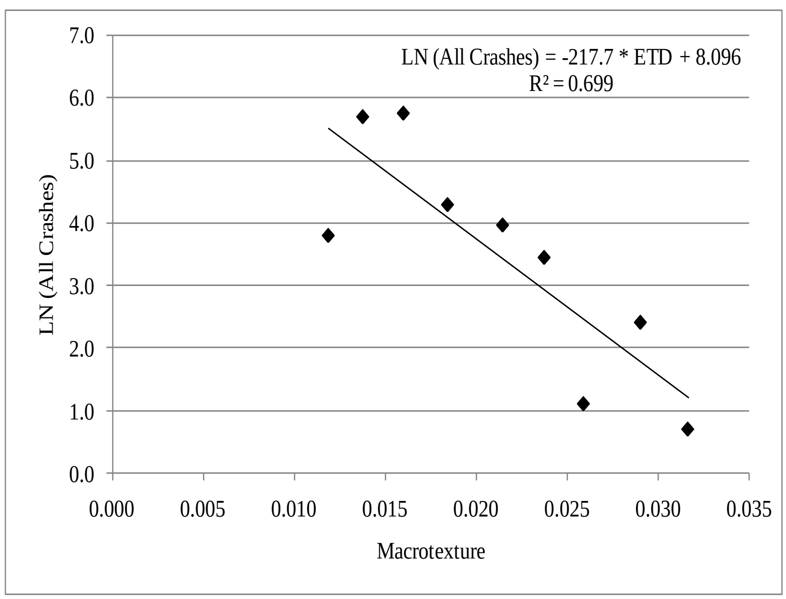
### *6.1.6 I-40 (Westbound Direction) in Pender County*

Figure 18 (a) shows the scatter plot between crashes (y-axis) and pavement macrotexture (x-axis) for outside lane on I-40 (westbound direction) in Durham County. It can be observed from Figure 18(a) that, in general, the number of crashes decreases as pavement macrotexture increases. Likewise, Figure 18(b) shows the scatter plot between logarithm of crashes (y-axis) and pavement macrotexture (x-axis) for the same corridor in Figure 18(a). It can also be seen from Figure 18(b) that the logarithm of crashes decreases as pavement macrotexture increases.

Statistical parameters from linear regression analysis (Table 8) indicate that there is a statistically significant relationship between 1) crashes and pavement macrotexture and 2) logarithm of crashes and pavement macrotexture for this corridor. Similar results were observed when analyzed considering dry crashes, wet crashes, injury crashes and PDO crashes. As there are no fatal crashes on this corridor in westbound direction, no results were obtained in case of fatal crashes. The coefficient for pavement macrotexture is negative indicating that the number of crashes decreases as pavement macrotexture increases. T-Statistic is greater than 2 and P-Value is always less than 0.07 (93 percent confidence level) for all the crash types except for fatal crashes. The difference between $R^2$ and $R^2$ (Adjusted) is reasonably low indicating a good fit. F-Statistic is greater than 4 in all cases except for fatal crashes. A comparison of T-Statistic and P-Value for pavement macrotexture, $R^2$, PRESS and F-Statistic for crashes and logarithm of crashes, shows that, a stronger and better relationship exists between logarithm of crashes and pavement macrotexture than when compared to crashes.




(a) All Crashes and Macrotexture




(b) LN (All Crashes) and Macrotexture

Figure 18. Scatter Plots –I-40 (Westbound Direction) in Pender County

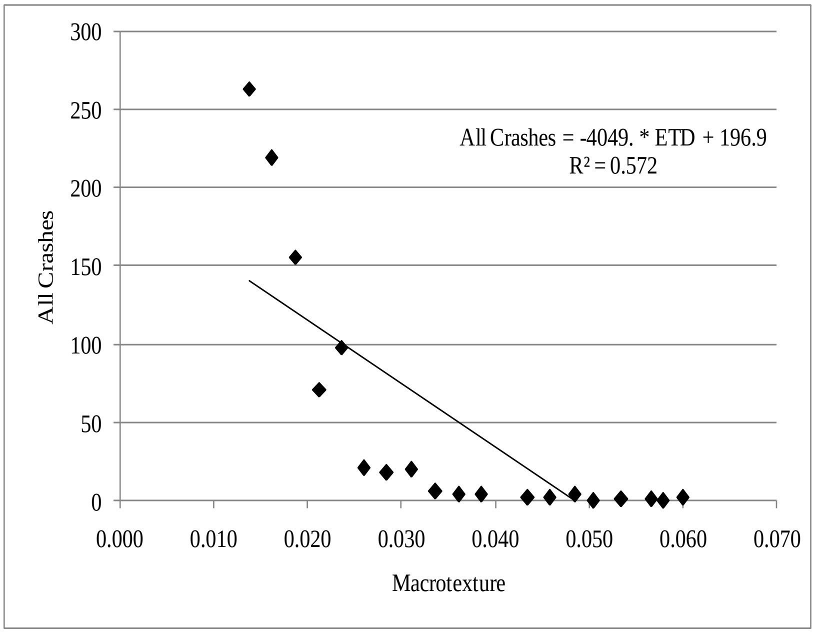
Table 8. Summary of Statistical Parameters from Bivariate Analysis –
I-40 (Westbound Direction) in Pender County

| Parameters | Crashes Vs. Macrotexture | | | | | | LN of Crashes Vs. Macrotexture | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | All | Dry | Wet | Fatal | Injury | PDO | All | Dry | Wet | Fatal | Injury | PDO |
| **Constant** | 333.90 | 269.47 | 52.82 | | 77.76 | 245.09 | 8.10 | 7.78 | 5.70 | | 6.3 | 7.57 |
| **Coefficient** | -11389 | -9256 | -1762 | | -2671 | -8332 | -218 | -215 | -173 | | -195 | -204 |
| **T-Statistic** | -2.21 | -2.18 | -2.45 | | -2.28 | -2.19 | -4.03 | -4.26 | -3.97 | | -4.260 | -3.99 |
| **P-Value** | 0.063 | 0.065 | 0.044 | | 0.057 | 0.065 | 0.005 | 0.004 | 0.005 | | 0.00 | 0.005 |
| **$R^2$** | 41.20 | 40.50 | 46.20 | | 42.60 | 40.70 | 69.90 | 72.20 | 69.20 | | 72.20 | 69.40 |
| **$R^2$ (Adj.)** | 32.70 | 32.00 | 38.50 | | 34.40 | 32.20 | 65.60 | 68.20 | 64.80 | | 68 | 65.10 |
| **PRESS Value** | 129842 | 88309 | 2441 | | 6535 | 71214 | 14 | 13 | 9 | | 10 | 13 |
| **F-Statistic** | 4.90 | 4.77 | 6.01 | | 5.19 | 4.80 | 16.26 | 18.17 | 15.75 | | 18.2 | 15.89 |

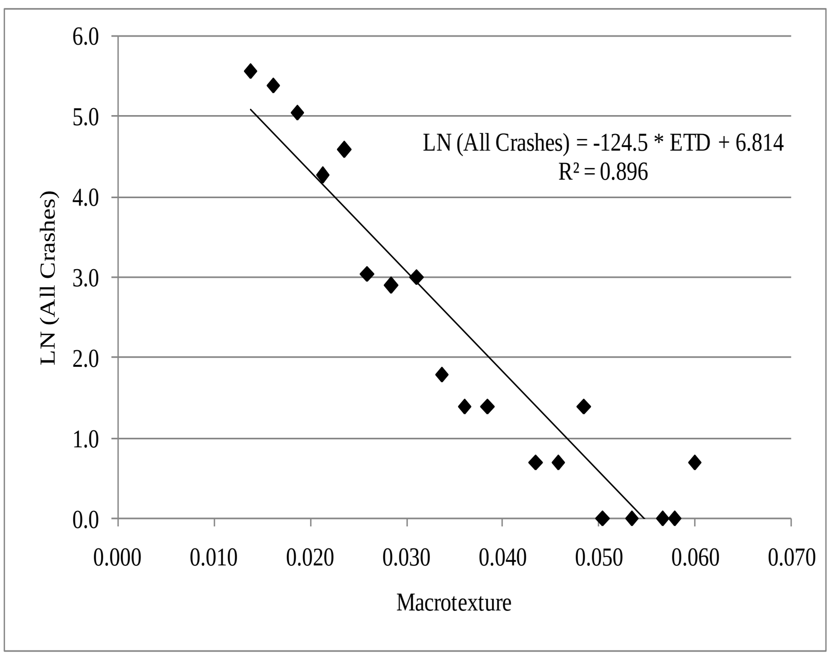
### *6.1.7 US-64 (Eastbound Direction) in Martin County*

Figure 19 (a) shows the scatter plot between crashes (y-axis) and pavement macrotexture (x-axis) for outside lane on US-64 (eastbound direction) in Martin County. It can be observed from Figure 19(a) that, in general, the number of crashes decreases as pavement macrotexture increases. Likewise, Figure 19(b) shows the scatter plot between logarithm of crashes (y-axis) and pavement macrotexture (x-axis) for the same corridor in Figure 19(a). It can also be seen from Figure 19(b) that the logarithm of crashes decreases as pavement macrotexture increases.

Statistical parameters from linear regression analysis (Table 9) indicate that there is a statistically significant relationship between 1) crashes and pavement macrotexture and 2) logarithm of crashes and pavement macrotexture for this corridor. Similar results were observed when analyzed considering dry crashes, wet crashes, injury crashes and PDO crashes. The coefficient for pavement macrotexture is negative indicating that the number of crashes decreases as pavement macrotexture increases. T-Statistic is greater than 2 and P-Value is less than 0.05 (95 percent confidence level) for all the crash types except for fatal crashes. The difference between $R^2$ and $R^2$ (Adjusted) is low indicating a good fit. F-Statistic is greater than 4 in all cases except for the fatal crashes. A comparison of T-Statistic and P-Value for pavement macrotexture, $R^2$, PRESS and F-Statistic for crashes and logarithm of crashes shows that, a stronger and better relationship exists between logarithm of crashes and pavement macrotexture than when compared to crashes.




(a) All Crashes and Macrotexture




(b) LN (All Crashes) and Macrotexture

Figure 19. Scatter Plots - US-64 (Eastbound Direction) in Martin County

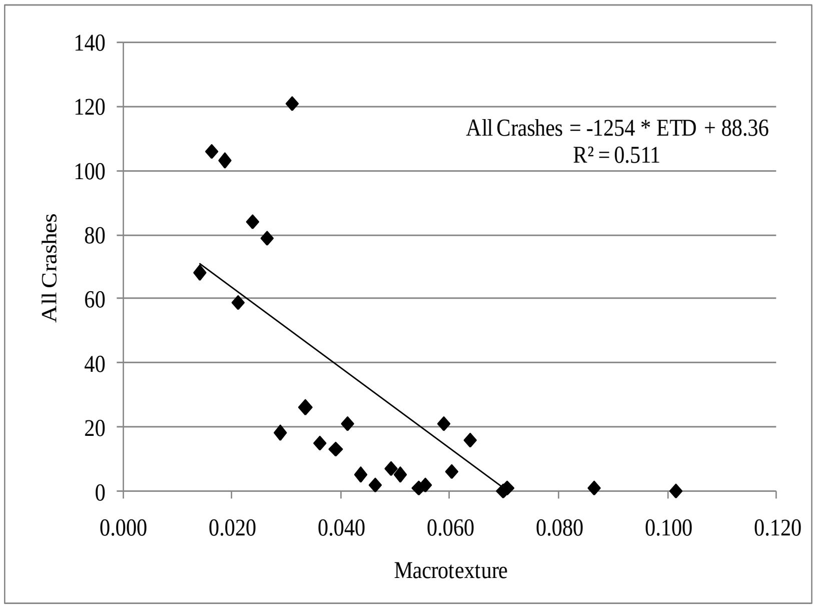
Table 9. Summary of Statistical Parameters from Bivariate Analysis – US-64 (Eastbound Direction) in Martin County

| Parameters | Crashes Vs. Macrotexture | | | | | | LN of Crashes Vs. Macrotexture | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | All | Dry | Wet | Fatal | Injury | PDO | All | Dry | Wet | Fatal | Injury | PDO |
| **Constant** | 196.96 | 145.76 | 39.05 | 0.54 | 46.12 | 147.54 | 6.81 | 6.46 | 4.09 | 0.03 | 4.40 | 6.41 |
| **Coefficient** | -4049 | -2998 | -802.6 | -7.3 | -946.6 | -3038 | -124.5 | -122.9 | -82.6 | 0.2 | -86.3 | -121.7 |
| **T-Statistic** | -4.77 | -4.75 | -4.26 | -0.82 | -4.63 | -4.79 | -12.15 | -11.77 | -5.93 | 0.10 | -6.41 | -9.71 |
| **P-Value** | 0.000 | 0.000 | 0.001 | 0.422 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.924 | 0.000 | 0.000 |
| **$R^2$** | 57.30 | 57.00 | 51.60 | 3.80 | 55.70 | 57.40 | 89.70 | 89.10 | 67.40 | 0.10 | 70.70 | 84.70 |
| **$R^2$ (Adj.)** | 54.70 | 54.50 | 48.80 | 0.00 | 53.10 | 54.90 | 89.10 | 88.40 | 65.50 | 0.00 | 69.00 | 83.80 |
| **PRESS Value** | 66114 | 36880 | 3237 | 6 | 3817 | 37038 | 9 | 9 | 17 | 1 | 16 | 13 |
| **F-Statistic** | 22.78 | 22.52 | 18.13 | 0.68 | 21.40 | 22.93 | 147.63 | 138.64 | 35.15 | 0.01 | 41.06 | 94.27 |

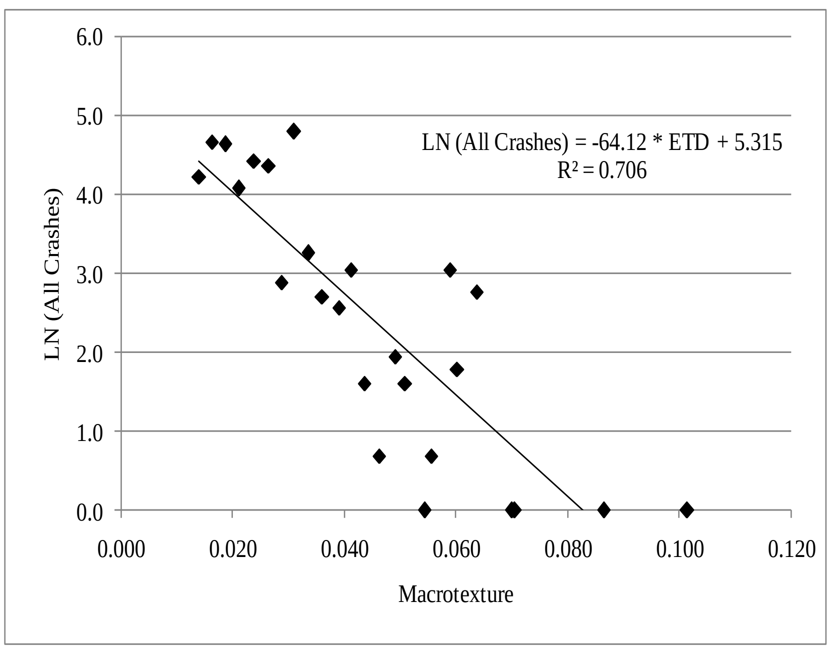
### *6.1.8 US-64 (Westbound Direction) in Martin County*

Figure 20 (a) shows the scatter plot between crashes (y-axis) and pavement macrotexture (x-axis) for outside lane on US-64 (westbound direction) in Martin County. It can be observed from Figure 20(a) that, in general, the number of crashes decreases as pavement macrotexture increases. Likewise, Figure 20(b) shows the scatter plot between logarithm of crashes (y-axis) and pavement macrotexture (x-axis) for the same corridor in Figure 20(a). It can also be seen from Figure 20(b) that the logarithm of crashes decreases as pavement macrotexture increases.

Statistical parameters from linear regression analysis (Table 10) indicate that there is a statistically significant relationship between 1) crashes and pavement macrotexture and 2) logarithm of crashes and pavement macrotexture for this corridor. Similar results were observed when analyzed considering dry crashes, wet crashes, injury crashes and PDO crashes. As there are no fatal crashes on this corridor in westbound direction, no results were obtained in case of fatal crashes. The coefficient for pavement macrotexture is negative indicating that the number of crashes decreases as pavement macrotexture increases. T-Statistic is greater than 4 and P-Value is 0 (100 percent confidence level) for all the crash types except for fatal crashes. The difference between $R^2$ and $R^2$ (Adjusted) is low indicating a good fit. F-Statistic is greater than 20 in all cases except for the fatal crashes. A comparison of T-Statistic and P-Value for pavement macrotexture, $R^2$, PRESS and F-Statistic for crashes and logarithm of crashes, shows that, a stronger and better relationship exists between logarithm of crashes and pavement macrotexture than when compared to crashes.




(a) All Crashes and Macrotexture




(b) LN (All Crashes) and Macrotexture

Figure 20. Scatter Plots –US-64 (Westbound Direction) in Martin County

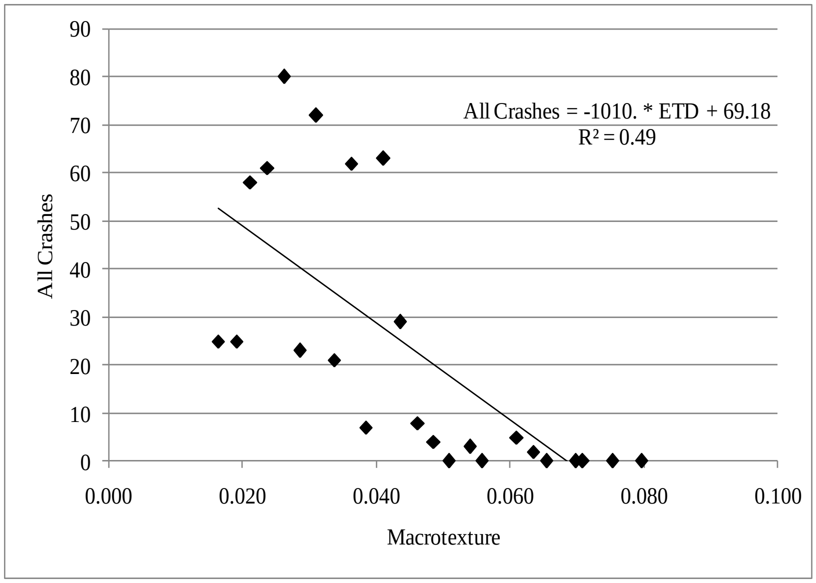
Table 10. Summary of Statistical Parameters from Bivariate Analysis – US-64 (Westbound Direction) in Martin County

| Parameters | Crashes Vs. Macrotexture | | | | | | LN of Crashes Vs. Macrotexture | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | All | Dry | Wet | Fatal | Injury | PDO | All | Dry | Wet | Fatal | Injury | PDO |
| **Constant** | 88.36 | 67.63 | 14.39 | | 21.72 | 64.57 | 5.32 | 4.93 | 2.84 | | 3.30 | 4.84 |
| **Coefficient** | -1254 | -952.8 | -209.5 | | -314.9 | -911.1 | -61.1 | -59.5 | -41.4 | | -44.4 | -59.9 |
| **T-Statistic** | -4.90 | -4.61 | -5.29 | | -5.15 | -4.58 | -7.45 | -7.15 | -6.11 | | -5.99 | -6.68 |
| **P-Value** | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 |
| **$R^2$** | 51.10 | 48.00 | 54.90 | | 53.60 | 47.70 | 70.70 | 69.00 | 61.90 | | 60.90 | 66.00 |
| **$R^2$ (Adj.)** | 49.00 | 45.70 | 52.90 | | 51.60 | 45.50 | 69.40 | 67.60 | 60.20 | | 59.20 | 64.50 |
| **PRESS Value** | 21824 | 14131 | 542 | | 1275 | 13044 | 24 | 22 | 16 | | 18 | 26 |
| **F-Statistic** | 24.05 | 21.22 | 28.00 | | 26.54 | 21.02 | 55.48 | 51.14 | 37.37 | | 35.85 | 44.65 |

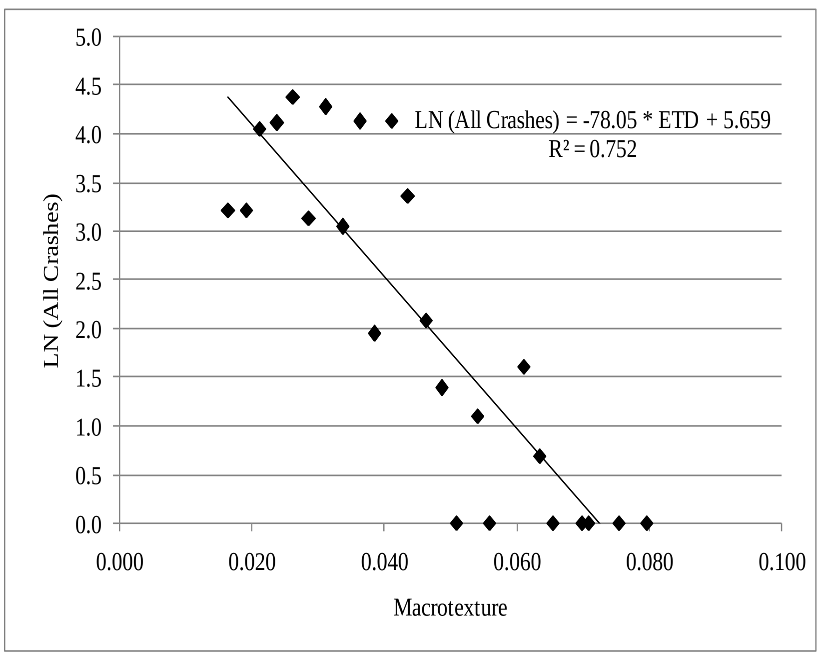
### *6.1.9 NC-42 (Eastbound Direction) in Johnston County*

Figure 21 (a) shows the scatter plot between crashes (y-axis) and pavement macrotexture (x-axis) for NC-42 (eastbound direction) in Johnston County. It can be observed from Figure 21(a) that, in general, the number of crashes decreases as pavement macrotexture increases. Likewise, Figure 21(b) shows the scatter plot between logarithm of crashes (y-axis) and pavement macrotexture (x-axis) for the same corridor in Figure 21(a). It can also be seen from Figure 21(b) that the logarithm of crashes decreases as pavement macrotexture increases.

Statistical parameters from linear regression analysis (Table 11) indicate that there is a statistically significant relationship between 1) crashes and pavement macrotexture and 2) logarithm of crashes and pavement macrotexture for this corridor. Similar results were observed when analyzed considering dry crashes, wet crashes, injury crashes and PDO crashes. There were a couple of sections with a fatal crash resulting in a zero value when logarithm is applied to fatal crashes, and hence no statistical results. The coefficient for pavement macrotexture is negative indicating that the number of crashes decreases as pavement macrotexture increases. T-Statistic is greater than 3 and P-Value is less than 0.02 (98 percent confidence level) for all the crash types except for fatal crashes. The difference between $R^2$ and $R^2$ (Adjusted) is low indicating a good fit. F-Statistic is greater than 10 in all cases except for the fatal crashes. A comparison of T-Statistic and P-Value for pavement macrotexture, $R^2$, PRESS and F-Statistic for crashes and logarithm of crashes, shows that, a stronger and better relationship exists between logarithm of crashes and pavement macrotexture than when compared to crashes.




(a) All Crashes and Macrotexture




(b) LN (All Crashes) and Macrotexture

Figure 21. Scatter Plots –NC-42 (Eastbound Direction) in Johnston County

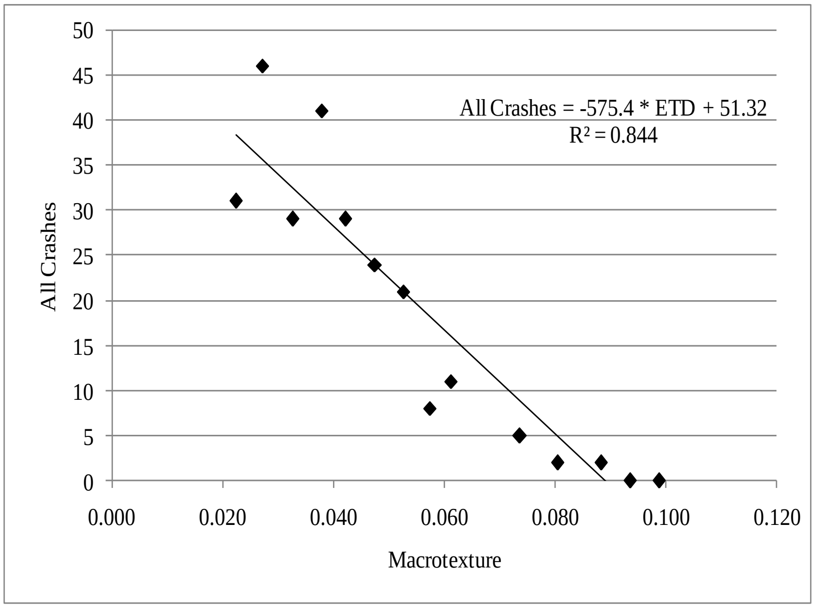
Table 11. Summary of Statistical Parameters from Bivariate Analysis – NC-42 (Eastbound Direction) in Johnston County

| Parameters | Crashes Vs. Macrotexture | | | | | | LN of Crashes Vs. Macrotexture | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | All | Dry | Wet | Fatal | Injury | PDO | All | Dry | Wet | Fatal | Injury | PDO |
| **Constant** | 69.19 | 54.93 | 11.24 | 0.12 | 25.61 | 41.49 | 5.66 | 5.29 | 2.62 | | 3.93 | 4.89 |
| **Coefficient** | -1011 | -804.4 | -159.7 | -0.9 | -374.0 | -604.7 | -78.1 | -73.7 | -37.6 | | -57.1 | -69.2 |
| **T-Statistic** | -4.60 | -4.59 | -3.47 | -0.27 | -3.97 | -4.52 | -8.18 | -8.12 | -4.28 | | -5.77 | -7.72 |
| **P-Value** | 0.000 | 0.000 | 0.002 | 0.789 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 |
| **$R^2$** | 49.00 | 48.90 | 35.30 | 0.30 | 41.70 | 48.20 | 75.30 | 75.00 | 45.50 | | 60.20 | 73.00 |
| **$R^2$ (Adj.)** | 46.70 | 46.60 | 32.40 | 0.00 | 39.10 | 45.80 | 74.10 | 73.80 | 43.00 | | 58.40 | 71.80 |
| **PRESS Value** | 10349 | 6603 | 444 | 2 | 1955 | 3772 | 19 | 17 | 16 | | 21 | 17 |
| **F-Statistic** | 21.15 | 21.08 | 12.02 | 0.07 | 15.75 | 20.44 | 66.93 | 65.92 | 18.34 | | 33.30 | 59.59 |

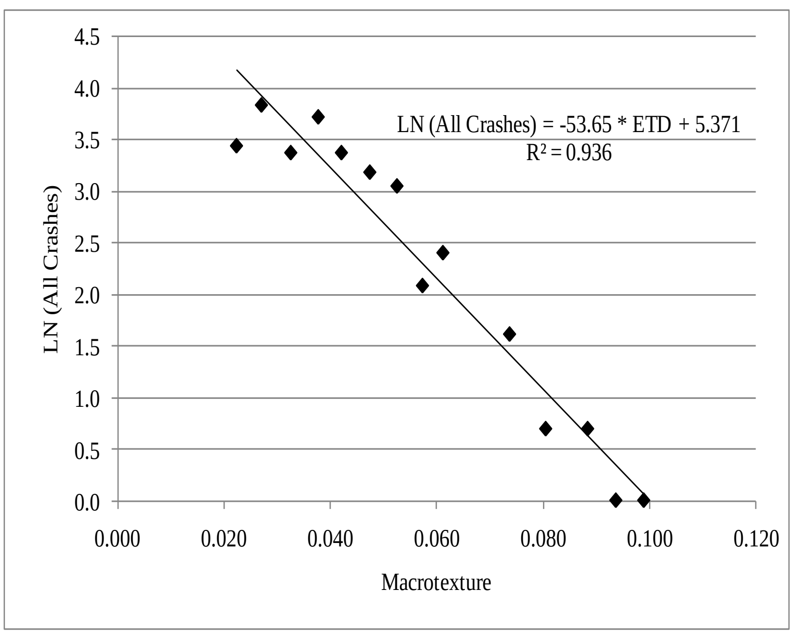
### *6.1.10 NC-48 (Northbound Direction) in Nash County*

Figure 22 (a) shows the scatter plot between crashes (y-axis) and pavement macrotexture (x-axis) for NC-48 (northbound direction) in Nash County. It can be observed from Figure 22(a) that, in general, the number of crashes decreases as pavement macrotexture increases. Likewise, Figure 22(b) shows the scatter plot between logarithm of crashes (y-axis) and pavement macrotexture (x-axis) for the same corridor in Figure 22(a). It can also be seen from Figure 22(b) that the logarithm of crashes decreases as pavement macrotexture increases.

Statistical parameters from linear regression analysis (Table 12) indicate that there is a statistically significant relationship between 1) crashes and pavement macrotexture and 2) logarithm of crashes and pavement macrotexture for this corridor. Similar results were observed when analyzed considering dry crashes, wet crashes, injury crashes and PDO crashes. As there are no fatal crashes on this corridor in the northbound direction, no results were obtained in case of fatal crashes. The coefficient for pavement macrotexture is negative indicating that the number of crashes decreases as pavement macrotexture increases. T-Statistic is greater than 2 and P-Value is almost 0 (100 percent confidence level) for all the crash types except for fatal crashes. The difference between $R^2$ and $R^2$ (Adjusted) is low indicating a good fit. F-Statistic is greater than 20 in all cases except for the fatal crashes. A comparison of T-Statistic and P-Value for pavement macrotexture, $R^2$, PRESS and F-Statistic for crashes and logarithm of crashes, shows that, a stronger and better relationship exists between logarithm of crashes and pavement macrotexture than when compared to crashes.




(a) All Crashes and Macrotexture




(b) LN (All Crashes) and Macrotexture

Figure 22. Scatter Plots –NC-48 (Northbound Direction) in Nash County

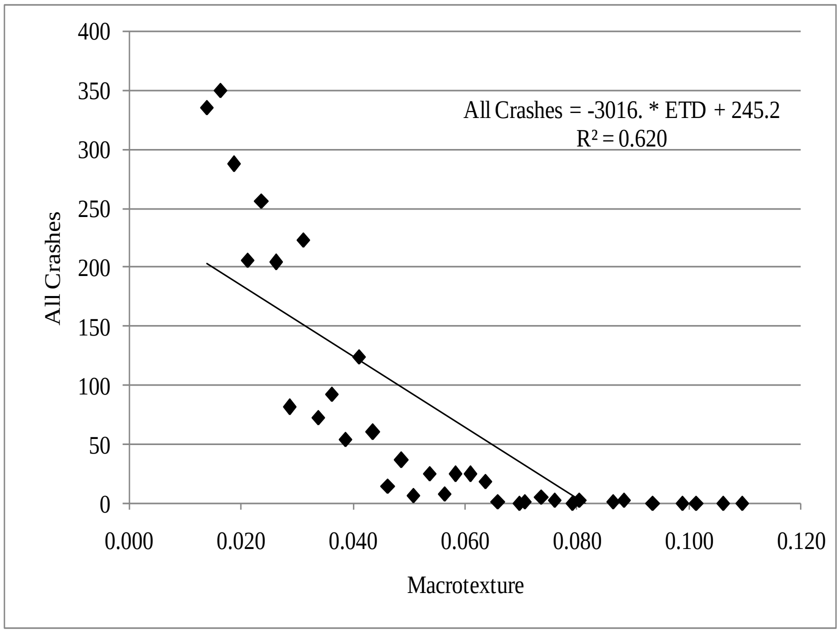
Table 12. Summary of Statistical Parameters from Bivariate Analysis –
NC-48 (Northbound Direction) in Nash County

| Parameters | Crashes Vs. Macrotexture | | | | | | LN of Crashes Vs. Macrotexture | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | All | Dry | Wet | Fatal | Injury | PDO | All | Dry | Wet | Fatal | Injury | PDO |
| **Constant** | 51.33 | 42.20 | 7.15 | | 14.95 | 35.47 | 5.37 | 5.12 | 2.34 | | 3.54 | 4.84 |
| **Coefficient** | -575.4 | -475.2 | -76.0 | | -167.1 | -398.9 | -53.7 | -52.7 | -25.7 | | -39.4 | -50.0 |
| **T-Statistic** | -8.08 | -7.28 | -4.61 | | -6.52 | -7.04 | -13.29 | -13.13 | -5.10 | | -7.98 | -13.82 |
| **P-Value** | 0.000 | 0.000 | 0.001 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 |
| **$R^2$** | 84.50 | 81.50 | 63.90 | | 78.00 | 80.50 | 93.60 | 93.50 | 68.40 | | 84.10 | 94.10 |
| **$R^2$ (Adj.)** | 83.20 | 80.00 | 60.90 | | 76.20 | 78.90 | 93.10 | 93.00 | 65.80 | | 82.80 | 93.60 |
| **PRESS Value** | 701 | 597 | 36 | | 84 | 433 | 2 | 2 | 3 | | 3 | 2 |
| **F-Statistic** | 65.22 | 53.01 | 21.25 | | 42.54 | 49.63 | 176.58 | 172.49 | 26.01 | | 63.65 | 191.08 |

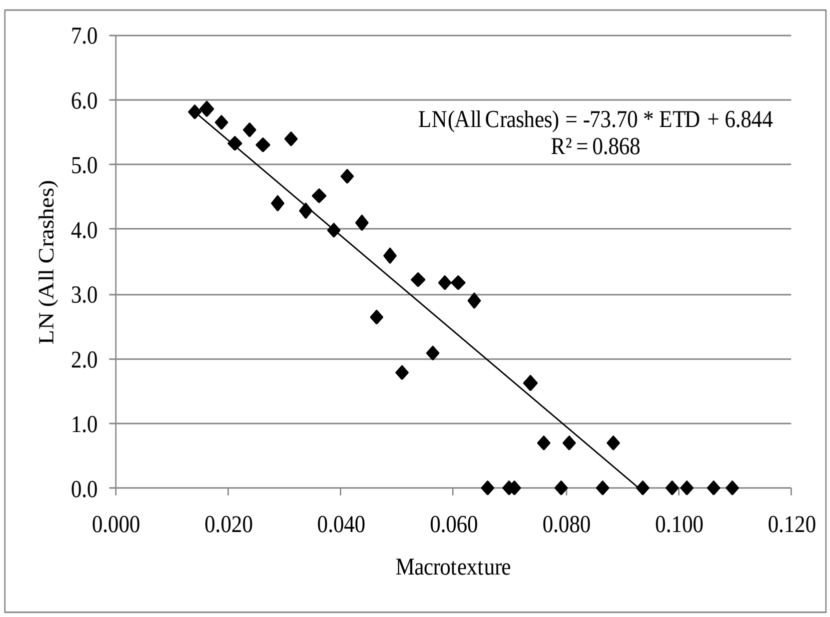
### *6.1.11 Highways*

Data for all the highways with asphalt pavement (US-64 in Martin County, NC-42 in Johnston County, and NC-48 in Nash County) were combined to generate a large sample size with a wide range of sections with pavement macrotexture and crashes. Figure 23 (a) shows the scatter plot between crashes (y-axis) and pavement macrotexture (x-axis) for all the highways combined together. A decrease in crashes with an increase in pavement macrotexture can be observed from the Figure 23(a). Likewise, Figure 23(b) shows the scatter plot between logarithm of crashes (y-axis) and pavement macrotexture (x-axis) for all the highways combined together. It can also be observed from Figure 23(b) that logarithm of crashes decreases as pavement macrotexture increases.

Statistical parameters from linear regression analysis (Table 13) indicate that there is a statistically significant relationship between 1) crashes and pavement macrotexture and 2) logarithm of crashes and pavement macrotexture when data for all highways was combined. Similar results were observed when analyzed considering dry crashes, wet crashes, fatal crashes, injury crashes and PDO crashes. The coefficient for pavement macrotexture is negative indicating that the number of crashes decreases as pavement macrotexture increases. T-Statistic is greater than 2 and P-Value is 0 (100 percent confidence level) for all the crash types except for fatal crashes. The statistical parameters obtained for fatal crashes (both linear and log-linear) in this case indicate that a stronger relationship than observed in case of individual study corridors exists between pavement macrotexture and fatal crashes. The lack of relationship in case of individual corridors could be attributed to low fatal crashes on each study corridor.




(a) All Crashes and Macrotexture




(b) LN (All Crashes) and Macrotexture

Figure 23. Scatter Plots – Highways

The difference between $R^2$ and $R^2$ (Adjusted) is low indicating a good fit. F-Statistic is greater than 4 and P-Value is 0.00 in all cases except for the fatal crashes. A comparison of T-Statistic and P-Value for pavement macrotexture, $R^2$, PRESS and F-Statistic for crashes and logarithm of crashes, shows that, a stronger and better relationship exists between logarithm of crashes and pavement macrotexture than when compared to crashes.

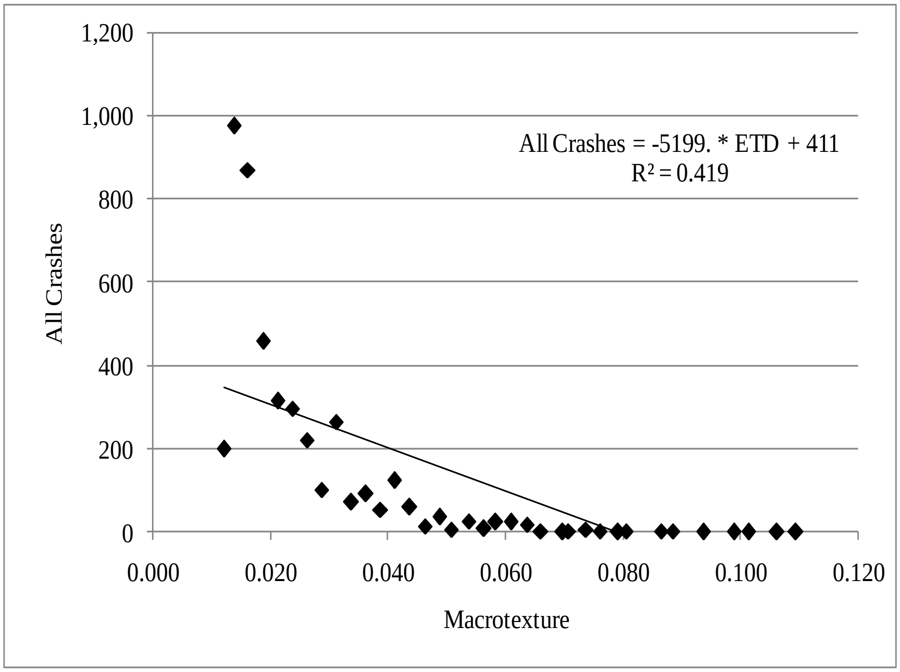
Table 13. Summary of Statistical Parameters from Bivariate Analysis – Highways

| Parameters | Crashes Vs. Macrotexture | | | | | | LN of Crashes Vs. Macrotexture | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | All | Dry | Wet | Fatal | Injury | PDO | All | Dry | Wet | Fatal | Injury | PDO |
| Constant | 245.00 | 187.25 | 43.41 | 0.56 | 65.24 | 174.62 | 6.85 | 6.51 | 4.26 | 0.12 | 4.99 | 6.31 |
| Coefficient | -3017 | -2298 | -536 | -6 | -800 | -2152 | -73.7 | -71.0 | -49.8 | -1.5 | -56.8 | -69.0 |
| T-Statistic | -7.35 | -7.50 | -6.40 | -1.96 | -7.59 | -7.09 | -14.72 | -14.40 | -10.57 | -1.47 | -12.28 | -13.83 |
| P-Value | 0.000 | 0.000 | 0.000 | 0.058 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.150 | 0.000 | 0.000 |
| $R^2$ | 62.10 | 63.00 | 55.40 | 10.40 | 63.60 | 60.40 | 86.80 | 86.30 | 77.20 | 6.20 | 82.10 | 85.30 |
| $R^2$ (Adj.) | 60.90 | 61.90 | 54.00 | 7.70 | 62.50 | 59.20 | 86.40 | 85.80 | 76.50 | 3.30 | 81.50 | 84.80 |
| PRESS Value | 168568 | 93785 | 7092 | 10 | 11059 | 92264 | 24 | 23 | 22 | 1 | 21 | 24 |
| F-Statistic | 54.05 | 56.25 | 40.95 | 3.84 | 57.62 | 50.34 | 216.82 | 207.27 | 111.71 | 2.17 | 150.91 | 191.37 |

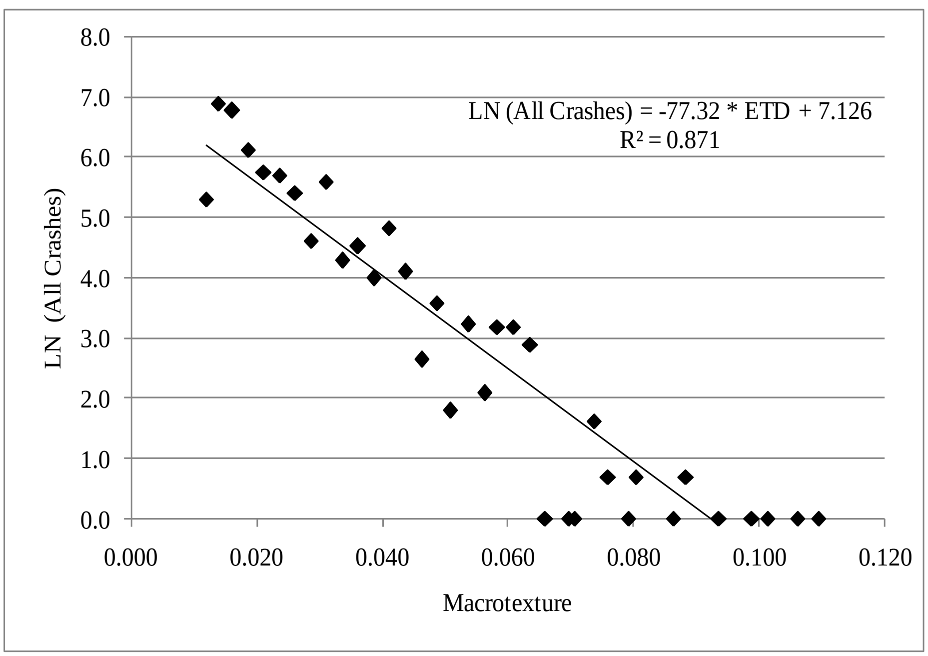
### *6.1.12 Highways and I-40 in Pender County*

Attempts were made to study the relationship between pavement macrotexture and crashes by combining data from Interstate freeways with the highways. Only I-40 in Pender County with asphalt pavement was used to represent Interstate freeways as pavement type (tined concrete) and range of pavement macrotexture values is different and relatively high in case of Durham County.

Figure 24 (a) shows the scatter plot between crashes (y-axis) and pavement macrotexture (x-axis) for highways and I-40 in Pender County combined together. It can be observed from Figure 24(a) that, in general, the number of crashes decreases as pavement macrotexture increases. Likewise, Figure 24(b) shows the scatter plot between logarithm of crashes (y-axis) and pavement macrotexture (x-axis) for highway and I-40 in Pender County combined together. It can also be seen from Figure 24(b) that the logarithm of crashes decreases as pavement macrotexture increases.




(a) All Crashes and Macrotexture




(b) LN (All Crashes) and Macrotexture

Figure 24. Scatter Plots – Highways and I40 in Pender County

Statistical parameters from linear regression analysis (Table 14) indicate that there is a statistically significant relationship between 1) crashes and pavement macrotexture and 2) logarithm of crashes and pavement macrotexture in this case. Similar results were observed when analyzed considering dry crashes, wet crashes, fatal crashes, injury crashes and PDO crashes. The coefficient for pavement macrotexture is negative indicating that the number of crashes decreases as pavement macrotexture increases. T-Statistic is generally greater than 3 and P-Value is nearly 0 (100 percent confidence level) for all the crash types. The difference between $R^2$ and $R^2$ (Adjusted) is low indicating a good fit. F-Statistic is greater than 7 in all the cases. A comparison of T-Statistic and P-Value for pavement macrotexture, PRESS and F-Statistic for crashes and logarithm of crashes, shows that, a stronger and better relationship exists between logarithm of crashes and pavement macrotexture than when compared to crashes.

Table 14. Summary of Statistical Parameters from Bivariate Analysis – Highways and I-40 in Pender County

| Parameters | Crashes Vs. Macrotexture | | | | | | LN of Crashes Vs. Macrotexture | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **All** | **Dry** | **Wet** | **Fatal** | **Injury** | **PDO** | **All** | **Dry** | **Wet** | **Fatal** | **Injury** | **PDO** |
| **Constant** | 410.99 | 315.71 | 73.49 | 0.95 | 102.91 | 298.17 | 7.13 | 6.78 | 4.66 | 0.27 | 5.29 | 6.61 |
| **Coefficient** | -5199 | -3990 | -933 | -11 | -1295 | -3779 | -77.3 | -74.5 | -55.0 | -3.4 | -60.7 | -73.0 |
| **T-Statistic** | -4.96 | -4.86 | -5.13 | -3.23 | -5.35 | -4.82 | -15.18 | -14.67 | -11.02 | -2.80 | -12.64 | -14.17 |
| **P-Value** | 0.000 | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.008 | 0.000 | 0.000 |
| **$R^2$** | 42.00 | 41.00 | 43.60 | 23.50 | 45.70 | 40.60 | 87.10 | 86.40 | 78.10 | 18.80 | 82.40 | 85.50 |
| **$R^2$ (Adj.)** | 40.30 | 39.20 | 41.90 | 21.30 | 44.10 | 38.90 | 86.80 | 86.00 | 77.50 | 16.40 | 81.90 | 85.10 |
| **PRESS Value** | 1240820 | 761995 | 37234 | 14 | 66033 | 693222 | 28 | 28 | 27 | 2 | 25 | 28 |
| **F-Statistic** | 24.58 | 23.61 | 26.28 | 10.46 | 28.63 | 23.25 | 230.46 | 215.28 | 121.42 | 7.85 | 159.72 | 200.74 |

### *6.1.13 Bivariate Analysis – Summary of Results*

Results from bivariate analysis indicate that a reasonably strong relationship exists between pavement macrotexture and crashes. The constant term is always positive and the coefficient for pavement macrotexture is always negative indicating crashes increase as pavement macrotexture decreases. The statistical parameters in case of fatal crashes on individual study corridors indicate a relatively weak or no relationship between pavement macrotexture and fatal crashes. It could be attributed to a fewer number of fatal crashes - low sample size to explain relationship using statistical analysis. Table 15 summarizes confidence level with which the relationship between pavement macrotexture and crashes can be explained for each study corridor and scenario.

It was felt that the $R^2$ values are relatively lower than expected indicating that pavement macrotexture cannot by itself explain crashes on roads. Also, there is a need to consider other predictor (independent) variables such as MVMT (traffic volume and length), number of interchanges, number of bridges, number of culverts, number of grade separated interchanges, number of at-grade intersections, and number of overhead signs, and study the relationship between pavement macrotexture and crashes when compared to these other predictor variables.

Table 15. Relationship Between Pavement Macrotexture and Crashes –
Summary Based on Confidence Level from Bivariate Analyses

| Corridor | Direction by Lane | Crashes Vs. Macrotexture | | | | | | LN of Crashes Vs. Macrotexture | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | All | Dry | Wet | Fatal | Injury | PDO | All | Dry | Wet | Fatal | Injury | PDO |
| I-40 in Durham | Eastbound - Outside Lane | 99.0 | 99.3 | 97.6 | 88.4 | 99.2 | 98.8 | 100.0 | 100.0 | 99.9 | | 100.0 | 100.0 |
| | Eastbound - Inside Lane | 99.9 | 99.9 | 99.3 | 80.3 | 99.9 | 99.8 | 100.0 | 100.0 | 100.0 | 69.9 | 100.0 | 100.0 |
| | Westbound - Outside Lane | 99.8 | 99.8 | 98.4 | | 99.8 | 99.8 | 100.0 | 100.0 | 93.5 | | 100.0 | 100.0 |
| | Westbound - Inside Lane | 99.7 | 99.6 | 97.9 | | 99.9 | 99.5 | 100.0 | 100.0 | 97.7 | | 100.0 | 100.0 |
| I-40 in Pender | Eastbound | 97.3 | 95.8 | 99.6 | 89.1 | 97.0 | 97.2 | 99.8 | 99.6 | 100.0 | 89.1 | 98.8 | 99.8 |
| | Westbound | 93.7 | 93.5 | 95.6 | | 94.3 | 93.5 | 99.5 | 99.6 | 99.5 | | 99.6 | 99.5 |
| US-64 in Martin | Eastbound | 100.0 | 100.0 | 99.9 | 57.8 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 7.6 | 100.0 | 100.0 |
| | Westbound | 100.0 | 100.0 | 100.0 | | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | | 100.0 | 100.0 |
| NC-42 in Johnston | Eastbound | 100.0 | 100.0 | 99.8 | 21.1 | 99.9 | 100.0 | 100.0 | 100.0 | 100.0 | | 100.0 | 100.0 |
| NC-48 in Nash | Northbound | 100.0 | 100.0 | 99.9 | | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | | 100.0 | 100.0 |
| Highways | | 100.0 | 100.0 | 100.0 | 94.2 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 85.0 | 100.0 | 100.0 |
| Highways and I40Pender | | 100.0 | 100.0 | 100.0 | 99.7 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 99.2 | 100.0 | 100.0 |

## 6.2 Multivariate Analyses

Bivariate analyses between logarithm of crashes and pavement macrotexture have generally shown that a strong relationship exists between the two variables. It is also well known and documented in literature that MVMT and roadway features influence crashes on roads. There is need to consider these variables and study the relationship between pavement macrotexture and crashes along with these other predictor variables.

Results from multivariate analyses to study the relationship between pavement macrotexture, MVMT, number of interchanges, number of bridges, number of culverts, number of grade separated interchanges, number of at-grade intersections, and number of overhead signs and crashes for each study corridor is discussed in the following subsections. Results based on analysis of dry crashes, wet crashes, fatal crashes, injury crashes and PDO crashes are also discussed. Both linear and log-linear relationships were tested. Stepwise regression with backward elimination technique is employed to eliminate variables that are less significant or variables whose P-Values are greater than 0.1 (less than 90 percent confidence level) and F-Statistic is less than 4.0. Thus, blank cells or cells with no values (coefficient C, T-Statistic T and P-Value P) for variables in tables for corridors discussed in this section indicate that these variables are statistically insignificant to explain crashes on the corridor based on results from the final step of backward elimination (shown in tables as "Step"). Standard deviation (S), $R^2$, $R^2$ (Adjusted), Mallows' Cp and predicted error in sum of squares (PRESS) are used to explain the goodness of fit.

### *6.2.1 I-40 (Eastbound Direction) in Durham County - Outside Lane*

Table 16 shows statistical parameters for models based on stepwise regression analysis for outside lane of I-40 (eastbound direction) in Durham County. It can be seen from the table that pavement macrotexture was found to have a significant impact on logarithm of all crashes, logarithm of dry crashes, logarithm of injury crashes and logarithm of PDO crashes. The coefficient for pavement macrotexture is negative in all these cases indicating that crashes decrease with increase in pavement macrotexture.

While linear and log-linear relationship between crashes and number of interchanges was found to be more predominant, the relationship between crashes and MVMT was found to be relatively less predominant on this corridor. The presence of bridges and culverts was found to decrease the number of crashes in some cases.

T-Statistic is generally greater than 2 and P-Value is less than 0.05 for predictor variables selected in the final step. Also, it is observed that S and PRESS are low when logarithm of crashes was used. However, $R^2$ was higher when crashes were used than when compared to logarithm of crashes.

While lack of linear or log-linear relationship between fatal crashes or wet crashes and pavement macrotexture is one possibility, it was also felt that insufficient sample size could be another reason for not being able to explain the relationship in case of fatal crashes.

### *6.2.2 I-40 (Eastbound Direction) in Durham County - Inside Lane*

Table 17 shows statistical parameters for models based on stepwise regression analysis for inside lane of I-40 (eastbound direction) in Durham County. It can be seen from the table that pavement macrotexture was found to have a significant impact on logarithm of all crashes, logarithm of dry crashes, logarithm of injury crashes and logarithm of PDO crashes as in the case of outside lane on the same corridor. The coefficient for pavement macrotexture is negative in all these cases indicating that crashes decrease with increase in pavement macrotexture. This was expected as the number of crashes on each section is same as in the previous case and a statistically insignificant variation in ETD was observed on lanes in the same travel direction (discussed in Chapter on "Calculation of Pavement Macrotexture").

While MVMT was found to have a significant relationship with crashes in all cases, the number of interchanges was found to have a significant relationship in case of all crashes, dry crashes, and PDO crashes. Bridges do not tend to follow any specific trends but the grade separated interchanges and overhead signs tend to decrease the number of crashes.

T-Statistic is generally greater than 2 and P-Value is less than 0.05 for predictor variables selected in the final step. Also, it is observed that S and PRESS are low when logarithm of crashes was used. However, $R^2$ was higher when crashes were used than when compared to logarithm of crashes. As in the previous case, while lack of linear or log-linear relationship between fatal crashes or wet crashes and pavement macrotexture is one possibility, low sample size could be another reason.

### *6.2.3 I-40 (Westbound Direction) in Durham County - Outside Lane*

Table 18 shows statistical parameters for models based on stepwise regression analysis for outside lane of I-40 (westbound direction) in Durham County. It can be seen from the table that pavement macrotexture was found to have a significant relationship with all crashes, dry crashes, injury crashes and PDO crashes and, with logarithm of all crashes, logarithm of dry crashes, and logarithm of PDO crashes. The coefficient for pavement macrotexture is negative in all these cases indicating that crashes decrease with increase in pavement macrotexture.

Table 16. Summary of Results from Multivariate Analysis –

Outside Lane of I-40 (Eastbound Direction) in Durham County

| **Crash Type** | | **All Crashes** | | **Dry Crashes** | | **Wet Crashes** | | **Fatal Crashes** | | **Injury Crashes** | | **PDO Crashes** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type** | | I | II | I | II | I | II | I | II | I | II | I | II |
| **Step** | | 3 | 6 | 3 | 6 | 6 | 6 | 6 | | 5 | 4 | 3 | 6 |
| **Constant** | | 1.712 | 3.915 | 2.763 | 3.72 | -2.127 | 0.147 | -0.109 | | 0.261 | 2.689 | 1.395 | 3.627 |
| **Predictors** | **Parameter** | | | | | | | | | | | | |
| **Macrotexture** | **C** | | -12.3 | | -13.1 | | | | | | -11.9 | | -12.5 |
| | **T** | | -4.1 | | -3.9 | | | | | | -4.4 | | -4.0 |
| | **P** | | 0.00 | | 0.00 | | | | | | 0.00 | | 0.00 |
| **Million Vehicle Miles of Travel** | **C** | 382 | | 267 | | 93 | 11.9 | 2.2 | | 90 | | 279 | |
| | **T** | 5.8 | | 5.9 | | 4.0 | 4.0 | 2.2 | | 4.8 | | 5.8 | |
| | **P** | 0.00 | | 0.00 | | 0.00 | 0.00 | 0.04 | | 0.00 | | 0.00 | |
| **# Interchanges** | **C** | 38.5 | 0.9 | 28.6 | 0.9 | 6.2 | 0.6 | 0.2 | | 6.8 | 0.9 | 30.1 | 1.0 |
| | **T** | 8.5 | 4.2 | 9.2 | 3.7 | 3.7 | 2.9 | 3.3 | | 5.1 | 4.4 | 9.0 | 4.1 |
| | **P** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| **# At-grade Intersections** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **# Bridges** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **# Culverts** | **C** | -23.0 | | -17.3 | | | | | | | -0.9 | -17.2 | |
| | **T** | -2.2 | | -2.5 | | | | | | | -1.8 | -2.3 | |
| | **P** | 0.04 | | 0.02 | | | | | | | 0.09 | 0.03 | |
| **# Grade Separated Interchanges** | **C** | -23.8 | | -17.0 | | | | | | -6.3 | -0.7 | -17.4 | |
| | **T** | -3.0 | | -3.2 | | | | | | -2.8 | -1.8 | -3.0 | |
| | **P** | 0.01 | | 0.01 | | | | | | 0.01 | 0.09 | 0.01 | |
| **# Overhead Signs** | **C** | -21.0 | | -14.1 | | | | | | | | -17.6 | |
| | **T** | -1.8 | | -1.9 | | | | | | | | -2.1 | |
| | **P** | 0.08 | | 0.08 | | | | | | | | 0.04 | |
| **S** | | 13.6 | 0.8 | 9.3 | 0.9 | 5.1 | 0.7 | 0.2 | | 4.1 | 0.7 | 10.0 | 0.8 |
| **R Square** | | 90.1 | 67.5 | 91.2 | 63.3 | 70.8 | 65.7 | 55.3 | | 79.7 | 70.5 | 90.7 | 66.4 |
| **R Square (Adj)** | | 87.7 | 64.8 | 89.1 | 60.3 | 68.4 | 62.8 | 51.6 | | 77.1 | 65.1 | 88.5 | 63.6 |
| **PRESS** | | 8512 | 16 | 3438 | 21 | 1242 | 13 | 2 | | 627 | 15 | 4658 | 18 |

**I = Crashes; II = LN (Crashes)**
**C = Coefficient; T = T-Statistic; P = P-Value;**

Table 17. Summary of Results from Multivariate Analysis –

Inside Lane of I-40 (Eastbound Direction) in Durham County

| **Crash Type** | | **All Crashes** | | **Dry Crashes** | | **Wet Crashes** | | **Fatal Crashes** | | **Injury Crashes** | | **PDO Crashes** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type** | | I | II | I | II | I | II | I | II | I | II | I | II |
| **Step** | | 3 | 5 | 4 | 5 | 5 | 5 | 5 | 6 | 5 | 6 | 3 | 5 |
| **Constant** | | 0.116 | 3.303 | 0.951 | 3.046 | -1.135 | 0.042 | -0.124 | -0.039 | 0.131 | 1.286 | 0.046 | 2.839 |
| **Predictors** | **Parameter** | | | | | | | | | | | | |
| **Macrotexture** | **C** | | -10.0 | | -9.8 | | | | | | -5.1 | | -9.3 |
| | **T** | | -3.3 | | -3.2 | | | | | | -1.7 | | -2.9 |
| | **P** | | 0.00 | | 0.00 | | | | | | 0.09 | | 0.01 |
| **Million Vehicle Miles of Travel** | **C** | 377 | 11.3 | 281 | 10.9 | 87 | 16.2 | 7.2 | 1.81 | 101 | 14 | 260 | 11.8 |
| | **T** | 7.2 | 3.0 | 7.5 | 2.8 | 5.3 | 6.3 | 6.1 | 4.3 | 6.8 | 3.8 | 6.9 | 2.9 |
| | **P** | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| **# Interchanges** | **C** | 23.9 | 0.4 | 13.4 | 0.5 | 7.7 | | | | 4.9 | | 17.8 | 0.5 |
| | **T** | 4.4 | 2.2 | 3.7 | 2.2 | 5.2 | | | | 3.7 | | 4.5 | 2.2 |
| | **P** | 0.00 | 0.04 | 0.00 | 0.04 | 0.00 | | | | 0.00 | | 0.00 | 0.03 |
| **# At-grade Intersections** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **# Bridges** | **C** | 8.6 | | 6.6 | | | 0.3 | -0.3 | -0.1 | | | 9.7 | |
| | **T** | 1.8 | | 2.0 | | | 2.1 | -3.9 | -2.5 | | | 2.9 | |
| | **P** | 0.08 | | 0.06 | | | 0.04 | 0.00 | 0.02 | | | 0.01 | |
| **# Culverts** | **C** | | | | | | | -0.5 | | | | | |
| | **T** | | | | | | | -1.8 | | | | | |
| | **P** | | | | | | | 0.08 | | | | | |
| **# Grade Separated Interchanges** | **C** | -14.4 | | -12.9 | | | -0.7 | | | | | -14.2 | |
| | **T** | -2.0 | | -2.5 | | | -2.1 | | | | | -2.7 | |
| | **P** | 0.06 | | 0.02 | | | 0.05 | | | | | 0.01 | |
| **# Overhead Signs** | **C** | -23.0 | | | | -9.9 | | | | -8.8 | | -15.1 | |
| | **T** | -1.9 | | | | -2.6 | | | | -2.5 | | -1.7 | |
| | **P** | 0.08 | | | | 0.02 | | | | 0.02 | | 0.10 | |
| **S** | | 11.8 | 0.7 | 8.6 | 0.7 | 4.0 | 0.6 | 0.3 | 0.1 | 3.6 | 0.7 | 8.5 | 0.8 |
| **R Square** | | 89.1 | 75.0 | 88.8 | 73.7 | 76.2 | 72.8 | 57.8 | 39.0 | 76.1 | 63.0 | 90.7 | 72.1 |
| **R Square (Adj)** | | 87.0 | 72.4 | 87.2 | 70.9 | 73.6 | 69.9 | 53.3 | 34.8 | 73.5 | 60.5 | 88.9 | 69.1 |
| **PRESS** | | 8121 | 18 | 3579 | 18 | 901 | 15 | | 1 | 599 | 17 | 3767 | 22 |

**I = Crashes; II = LN (Crashes)**
**C = Coefficient; T = T-Statistic; P = P-Value;**

While linear relationship between crashes and number of interchanges was found to be predominant, log-linear relationship between crashes and MVMT was found to be more predominant. The presence of bridges was found to decrease wet crashes whereas grade separated interchanges tend to increase the number of wet crashes.

T-Statistic is generally greater than 2 and P-Value is less than 0.05 for predictor variables selected in the final step. Also, it is observed that S and PRESS are low when logarithm of crashes was used. Even the $R^2$ was higher when logarithm of crashes was used than when compared to crashes.

### *6.2.4 I-40 (Westbound Direction) in Durham County - Inside Lane*

Table 19 shows statistical parameters for models based on stepwise regression analysis for inside lane of I-40 (westbound direction) in Durham County. It can be seen from the table that pavement macrotexture was found to have a significant relationship with all crashes, wet crashes, injury crashes, logarithm of all crashes, logarithm of dry crashes, logarithm of injury crashes and logarithm of PDO crashes. The coefficient for pavement macrotexture is negative in all these cases except in case of all crashes indicating that crashes decrease with increase in pavement macrotexture.

MVMT was the only predictor variable other than macrotexture to have an impact on dry crashes, injury crashes, PDO crashes, logarithms of all crashes, logarithm of dry crashes, logarithm of wet crashes, logarithm of injury crashes and logarithm of PDO crashes. The coefficient for MVMT is positive indicating that crashes increase with increase in MVMT.

T-Statistic is generally greater than 2 and P-Value is less than 0.05 for predictor variables selected in the final step. Also, it is observed that S and PRESS are low, $R^2$ values higher for logarithm of crashes when compared with crashes.

Table 18. Summary of Results from Multivariate Analysis – Outside Lane of I-40 (Westbound Direction) in Durham County

| **Crash Type** | | **All Crashes** | | **Dry Crashes** | | **Wet Crashes** | | **Fatal Crashes** | | **Injury Crashes** | | **PDO Crashes** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type** | | I | II | I | II | I | II | I | II | I | II | I | II |
| **Step** | | 5 | 5 | 5 | 5 | 3 | 3 | | | 6 | 6 | 5 | 5 |
| **Constant** | | 38.87 | 2.769 | 32.52 | 2.532 | 0.31 | 0.092 | | | 9.292 | 0.092 | 28.93 | 2.194 |
| **Predictors** | **Parameter** | | | | | | | | | | | | |
| **Macrotexture** | **C** | -206.0 | -11.7 | -173.0 | -11.2 | | | | | -48.0 | | -154.0 | -9.5 |
| | **T** | -3.3 | -2.4 | -3.3 | -2.3 | | | | | -3.5 | | -3.3 | -2.0 |
| | **P** | 0.00 | 0.03 | 0.00 | 0.03 | | | | | 0.00 | | 0.00 | 0.06 |
| **Million Vehicle Miles of Travel** | **C** | | 16.4 | | 16.4 | 46 | 9.9 | | | | 17.9 | | 18.2 |
| | **T** | | 2.1 | | 2.1 | 2.9 | 2.2 | | | | 4.4 | | 2.4 |
| | **P** | | 0.05 | | 0.05 | 0.01 | 0.04 | | | | 0.00 | | 0.02 |
| **# Interchanges** | **C** | 12.4 | | 11.7 | | 2.8 | 0.8 | | | | | 10.5 | |
| | **T** | 1.9 | | 2.1 | | 2.0 | 2.1 | | | | | 2.1 | |
| | **P** | 0.08 | | 0.05 | | 0.06 | 0.05 | | | | | 0.05 | |
| **# At-grade Intersections** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **# Bridges** | **C** | | | | | -3.6 | -0.9 | | | | | | |
| | **T** | | | | | -2.4 | -2.2 | | | | | | |
| | **P** | | | | | 0.02 | 0.04 | | | | | | |
| **# Culverts** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **# Grade Separated Interchanges** | **C** | | | | | 3.4 | 0.9 | | | | | | |
| | **T** | | | | | 2.3 | 2.2 | | | | | | |
| | **P** | | | | | 0.03 | 0.04 | | | | | | |
| **# Overhead Signs** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **S** | | 18.0 | 0.9 | 15.0 | 0.9 | 2.3 | 0.6 | | | 4.0 | 0.7 | 13.5 | 0.9 |
| **R Square** | | 37.7 | 59.7 | 39.6 | 58.5 | 42.4 | 36.5 | | | 29.9 | 40.4 | 39.2 | 59.1 |
| **R Square (Adj)** | | 33.1 | 56.7 | 35.2 | 55.4 | 33.2 | 26.3 | | | 27.4 | 38.2 | 34.7 | 56.1 |
| **PRESS** | | 11276 | 28 | 7929 | 28 | 201 | 14 | | | 537 | 17 | 6364 | 26 |

**I = Crashes; II = LN (Crashes)**
**C = Coefficient; T = T-Statistic; P = P-Value;**

Table 19. Summary of Results from Multivariate Analysis –

Inside Lane of I-40 (Westbound Direction) in Durham County

| **Crash Type** | | **All Crashes** | | **Dry Crashes** | | **Wet Crashes** | | **Fatal Crashes** | | **Injury Crashes** | | **PDO Crashes** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type** | | I | II | I | II | I | II | I | II | I | II | I | II |
| **Step** | | 6 | 5 | 6 | 5 | 6 | 6 | | | 5 | 5 | 6 | 5 |
| **Constant** | | -0.87 | 2.691 | -1.382 | 2.404 | 4.154 | 0.035 | | | 4.766 | 1.057 | -1.156 | 2.093 |
| **Predictors** | **Parameter** | | | | | | | | | | | | |
| **Macrotexture** | **C** | 444.0 | -11.4 | | -11.0 | -18.2 | | | | -27.0 | -6.0 | | -9.9 |
| | **T** | 3.8 | -3.2 | | -3.0 | -2.4 | | | | -1.9 | -1.9 | | -2.6 |
| | **P** | 0.00 | 0.00 | | 0.01 | 0.02 | | | | 0.06 | 0.06 | | 0.01 |
| **Million Vehicle Miles of Travel** | **C** | | 22.4 | 391 | 23.2 | | 11 | | | 52 | 14.3 | 348 | 24.3 |
| | **T** | | 3.2 | 3.9 | 3.2 | | 2.6 | | | 1.9 | 2.3 | 3.6 | 3.2 |
| | **P** | | 0.00 | 0.00 | 0.00 | | 0.02 | | | 0.07 | 0.03 | 0.00 | 0.00 |
| **# Interchanges** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **# At-grade Intersections** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **# Bridges** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **# Culverts** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **# Grade Separated Interchanges** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **# Overhead Signs** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **S** | | 16.8 | 0.8 | 14.5 | 0.8 | 2.1 | 0.6 | | | 3.1 | 0.7 | 13.7 | 0.8 |
| **R Square** | | 32.4 | 65.7 | 33.1 | 63.8 | 16.5 | 17.8 | | | 40.5 | 45.3 | 30.6 | 61.6 |
| **R Square (Adj)** | | 30.1 | 63.3 | 30.9 | 61.3 | 13.7 | 15.0 | | | 36.4 | 41.5 | 28.3 | 59.0 |
| **PRESS** | | 9935 | 22 | 7478 | 23 | 158 | 13 | | | 335 | 17 | 6638 | 24 |

**I = Crashes; II = LN (Crashes)**
**C = Coefficient; T = T-Statistic; P = P-Value;**

### *6.2.5 I-40 (Eastbound Direction) in Pender County*

Table 20 shows statistical parameters for models based on stepwise regression analysis for outside lane on I-40 (eastbound direction) in Pender County. It can be seen from the table that pavement macrotexture was found to have a significant relationship with all crashes, wet crashes, fatal crashes, PDO crashes, and logarithm of all crash types. The coefficient for pavement macrotexture is negative in all these cases indicating that crashes decrease with increase in pavement macrotexture.

Linear and log-linear relationship between crashes and MVMT was found to be more predominant. The presence of bridges was found to decrease logarithm of wet crashes and injury crashes whereas culverts and grade separated interchanges were found to decrease logarithm of wet crashes. The presence of interchanges tends to increase wet crashes while culverts were found to increase injury crashes and logarithm of injury crashes.

T-Statistic is generally greater than 2 and P-Value is less than 0.05 for predictor variables selected in the final step. Also, it is observed that S and PRESS are low when logarithm of crashes was used. However, $R^2$ was higher when crashes were used than when compared to logarithm of crashes.

### *6.2.6 I-40 (Westbound Direction) in Pender County*

Table 21 shows statistical parameters for models based on stepwise regression analysis for outside lane on I-40 (westbound direction) in Pender County. It can be seen from the table that pavement macrotexture was found to have a significant relationship with logarithm of all crashes, logarithm of dry crashes and logarithm of injury crashes. The coefficient for pavement macrotexture is negative in all these cases indicating that crashes decrease with increase in pavement macrotexture.

While linear relationship between crashes and MVMT was found to be more predominant, number of interchanges was found to increase wet crashes and logarithm of wet crashes. The number of culverts was found to increase all crashes, dry crashes, wet crashes and injury crashes. The number of grade separated interchanges was found to increase crashes and logarithm of crashes in all cases on this corridor.

Table 20. Summary of Results from Multivariate Analysis –

I-40 (Eastbound Direction) in Pender County

| **Crash Type** | | **All Crashes** | | **Dry Crashes** | | **Wet Crashes** | | **Fatal Crashes** | | **Injury Crashes** | | **PDO Crashes** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type** | | I | II | I | II | I | II | I | II | I | II | I | II |
| **Step** | | 5 | 5 | 6 | 6 | 5 | 1 | 4 | 4 | 5 | 6 | 5 | 5 |
| **Constant** | | 85.08 | 6.444 | 8.079 | 8.012 | 47.19 | 4.495 | 4.174 | 1.44 | 2.369 | 6.541 | 60.27 | 6.236 |
| **Predictors** | **Parameter** | | | | | | | | | | | | |
| **Macrotexture** | **C** | -2999 | -146.0 | | -217.0 | -1799 | -152.3 | -159.0 | -55.0 | | -201.0 | -2101 | -151.0 |
| | **T** | -3.7 | -3.1 | | -4.6 | -2.9 | -423.3 | -3.5 | -3.5 | | -3.6 | -3.4 | -3.5 |
| | **P** | 0.02 | 0.03 | | 0.00 | 0.03 | 0.00 | 0.03 | 0.03 | | 0.01 | 0.02 | 0.02 |
| **Million Vehicle Miles of Travel** | **C** | 897 | 4.9 | 805 | | 104 | 13.74 | -10.8 | -3.7 | 280 | | 674 | 4.9 |
| | **T** | 21.1 | 2.0 | 30.8 | | 3.3 | 336.3 | -3.0 | -3.0 | 12.1 | | 20.8 | 2.2 |
| | **P** | 0.00 | 0.10 | 0.00 | | 0.02 | 0.00 | 0.04 | 0.04 | 0.00 | | 0.00 | 0.08 |
| **# Interchanges** | **C** | | | | | | 1.5 | | | | | | |
| | **T** | | | | | | 244.8 | | | | | | |
| | **P** | | | | | | 0.00 | | | | | | |
| **# At-grade Intersections** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **# Bridges** | **C** | | | | | | -0.1 | | | | | | |
| | **T** | | | | | | -19.0 | | | | | | |
| | **P** | | | | | | 0.03 | | | | | | |
| **# Culverts** | **C** | | | | | | -1.2 | 0.8 | 0.3 | -5.4 | | | |
| | **T** | | | | | | -293.2 | 2.9 | 2.9 | -2.4 | | | |
| | **P** | | | | | | 0.00 | 0.05 | 0.05 | 0.07 | | | |
| **# Grade Separated Interchanges** | **C** | | | | | | -0.3 | | | | | | |
| | **T** | | | | | | -91.0 | | | | | | |
| | **P** | | | | | | 0.01 | | | | | | |
| **# Overhead Signs** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **S** | | 9.6 | 0.5 | 8.2 | 0.8 | 7.2 | 0.0 | 0.5 | 0.2 | 4.2 | 0.9 | 7.3 | 0.5 |
| **R Square** | | 99.5 | 89.8 | 99.4 | 78.2 | 92.5 | 100.0 | 81.9 | 81.9 | 98.4 | 67.8 | 99.5 | 91.3 |
| **R Square (Adj)** | | 99.4 | 85.7 | 99.3 | 74.6 | 89.5 | 100.0 | 68.4 | 68..9 | 97.8 | 62.5 | 99.3 | 87.8 |
| **PRESS** | | 1372 | 4 | 1168 | 6 | 1528 | 0 | 9 | 1 | 1063 | 9 | 1094 | 5 |

**I = Crashes; II = LN (Crashes)**
**C = Coefficient; T = T-Statistic; P = P-Value;**

Table 21. Summary of Results from Multivariate Analysis –

I-40 (Westbound Direction) in Pender County

| **Crash Type** | | **All Crashes** | | **Dry Crashes** | | **Wet Crashes** | | **Fatal Crashes** | | **Injury Crashes** | | **PDO Crashes** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type** | | I | II | I | II | I | II | I | II | I | II | I | II |
| **Step** | | 4 | 5 | 4 | 5 | 3 | 5 | | | 4 | 5 | 5 | 6 |
| **Constant** | | 4.129 | 6.248 | 0.824 | 5.839 | 0.834 | 0.935 | | | 1.05 | 4.508 | 3.193 | 2.362 |
| **Predictors** | **Parameter** | | | | | | | | | | | | |
| **Macrotexture** | **C** | | -156.0 | | -150.0 | | | | | | -136.0 | | |
| | **T** | | -3.2 | | -3.9 | | | | | | -3.9 | | |
| | **P** | | 0.02 | | 0.01 | | | | | | 0.01 | | |
| **Million Vehicle Miles of Travel** | **C** | 676 | | 592 | | -57 | | | | 97 | | 599 | |
| | **T** | 10.3 | | 15.8 | | -2.3 | | | | 5.6 | | 14.6 | |
| | **P** | 0.00 | | 0.00 | | 0.09 | | | | 0.00 | | 0.00 | |
| **# Interchanges** | **C** | | | | | 10.2 | 1.2 | | | | | | |
| | **T** | | | | | 5.5 | 2.1 | | | | | | |
| | **P** | | | | | 0.01 | 0.08 | | | | | | |
| **# At-grade Intersections** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **# Bridges** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **# Culverts** | **C** | 16.1 | | 12.2 | | 12.6 | | | | 8.4 | | | |
| | **T** | 2.3 | | 3.0 | | 5.5 | | | | 4.5 | | | |
| | **P** | 0.07 | | 0.03 | | 0.01 | | | | 0.01 | | | |
| **# Grade Separated Interchanges** | **C** | 24.0 | 0.6 | 16.9 | 0.6 | 9.8 | 0.8 | | | 7.9 | 0.6 | 15.9 | 1.0 |
| | **T** | 6.8 | 2.4 | 8.4 | 3.2 | 9.3 | 3.6 | | | 8.5 | 3.3 | 4.6 | 3.3 |
| | **P** | 0.00 | 0.05 | 0.00 | 0.02 | 0.00 | 0.01 | | | 0.00 | 0.02 | 0.00 | 0.01 |
| **# Overhead Signs** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **S** | | 6.9 | -0.8 | 3.9 | 0.6 | 1.7 | 0.8 | | | 1.8 | 0.6 | 6.9 | 1.1 |
| **R Square** | | 99.8 | 84.9 | 99.9 | 89.8 | 99.6 | 75.1 | | | 99.7 | 89.9 | 99.6 | 61.4 |
| **R Square (Adj)** | | 99.7 | 79.9 | 99.9 | 86.4 | 99.1 | 66.9 | | | 99.6 | 86.6 | 99.4 | 55.9 |
| **PRESS** | | 995 | 13 | 691 | 10 | 429 | 6.53.77 | | | 245 | 6 | 1292 | 23 |

**I = Crashes; II = LN (Crashes)**
**C = Coefficient; T = T-Statistic; P = P-Value;**

T-Statistic is generally greater than 2 and P-Value is less than 0.05 for predictor variables selected in the final step. Also, it is observed that S and PRESS are low when logarithm of crashes was used. However, $R^2$ was higher when crashes were used than when compared to logarithm of crashes.

### *6.2.7 US-64 (Eastbound Direction) in Martin County*

Table 22 shows statistical parameters for models based on stepwise regression analysis for outside lane on US-64 (eastbound direction) in Martin County. It can be seen from the table that pavement macrotexture was found to have a significant relationship with all crashes, dry crashes, fatal crashes, injury crashes, PDO crashes, logarithm of all crashes and logarithm of wet crashes. The coefficient for pavement macrotexture is negative in case of log-linear relation but positive for linear relation.

While linear and log-linear relationship between crashes and MVMT was found to be highly predominant, the number of interchanges, at-grade intersections and bridges do not follow any specific trends. The number of culverts and grade separated interchanges were found to decrease logarithm of dry crashes.

T-Statistic is generally greater than 2 and P-Value is less than 0.05 for predictor variables selected in the final step. Also, it is observed that S and PRESS are low when logarithm of crashes was used. $R^2$ is nearly equal for most the models.

### *6.2.8 US-64 (Westbound Direction) in Martin County*

Table 23 shows statistical parameters for models based on stepwise regression analysis for outside lane on US-64 (westbound direction) in Martin County. It can be seen from the table that pavement macrotexture has a significant relationship with all crashes, injury crashes, PDO crashes, logarithm of all crashes, logarithm of dry crashes, logarithm of wet crashes, logarithm of injury crashes and logarithm of PDO crashes. The coefficient for pavement macrotexture is negative in all these cases indicating that crashes decrease with increase in pavement macrotexture.

Table 22. Summary of Results from Multivariate Analysis –

US-64 (Eastbound Direction) in Martin County

| Crash Type | | All Crashes | | Dry Crashes | | Wet Crashes | | Fatal Crashes | | Injury Crashes | | PDO Crashes | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type | | I | II | I | II | I | II | I | II | I | II | I | II |
| Step | | 4 | 4 | 4 | 2 | 4 | 5 | 2 | 7 | 4 | 5 | 4 | 2 |
| Constant | | -55.45 | 3.637 | -41.2 | -0.128 | -0.74 | 1.782 | 2.608 | 0.036 | -19 | -0.062 | -41.15 | -0.138 |
| **Predictors** | **Parameter** | | | | | | | | | | | | |
| Macrotexture | C | 929.0 | -63.0 | 695.0 | | | -35.0 | -44.0 | | 332.0 | | 685.0 | |
| | T | 2.6 | -4.4 | 2.5 | | | -2.9 | -2.2 | | 3.1 | | 2.5 | |
| | P | 0.02 | 0.00 | 0.03 | | | 0.01 | 0.05 | | 0.01 | | 0.02 | |
| Million Vehicle Miles of Travel | C | 2616 | 25.8 | 1810 | 108 | 379 | | -52 | | 697 | 38 | 1934 | 112 |
| | T | 14.1 | 4.5 | 12.5 | 8.4 | 13.5 | | -2.6 | | 16.3 | 13.1 | 13.8 | 5.4 |
| | P | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.02 | | 0.00 | 0.00 | 0.00 | 0.00 |
| # Interchanges | C | | | | -1.9 | 12.0 | 1.7 | 1.8 | | | | | -1.8 |
| | T | | | | -3.9 | 7.2 | 5.5 | 2.2 | | | | | -2.3 |
| | P | | | | 0.00 | 0.00 | 0.00 | 0.04 | | | | | 0.04 |
| # At-grade Intersections | C | | 0.2 | | 0.6 | -1.8 | | -0.3 | | 0.9 | 0.2 | | 0.6 |
| | T | | 2.8 | | 8.6 | -7.9 | | -2.5 | | 1.8 | 5.7 | | 5.2 |
| | P | | 0.01 | | 0.00 | 0.00 | | 0.03 | | 0.09 | 0.00 | | 0.00 |
| # Bridges | C | 9.1 | | 10.9 | -0.6 | | | 0.6 | | | | 7.5 | -0.7 |
| | T | 2.7 | | 4.2 | -4.1 | | | 3.4 | | | | 3.0 | -2.9 |
| | P | 0.02 | | 0.00 | 0.00 | | | 0.01 | | | | 0.01 | 0.01 |
| # Culverts | C | | | | -0.8 | | | | | | | | |
| | T | | | | -3.5 | | | | | | | | |
| | P | | | | 0.00 | | | | | | | | |
| # Grade Separated Interchanges | C | | | | -0.8 | | | | | | | | -0.9 |
| | T | | | | -3.5 | | | | | | | | -2.3 |
| | P | | | | 0.00 | | | | | | | | 0.04 |
| # Overhead Signs | C | | | | | | | | | | | | |
| | T | | | | | | | | | | | | |
| | P | | | | | | | | | | | | |
| S | | 13.1 | 0.4 | 10.1 | 0.4 | 1.6 | 0.5 | 0.5 | 0.2 | 3.2 | 0.3 | 9.8 | 0.6 |
| R Square | | 97.8 | 96.1 | 97.6 | 97.5 | 99.3 | 88.7 | 49.3 | 0.0 | 97.7 | 95.7 | 97.8 | 93.8 |
| R Square (Adj) | | 97.3 | 95.3 | 97.1 | 96.6 | 99.1 | 87.2 | 29.7 | 0.0 | 97.2 | 95.1 | 97.3 | 91.4 |
| PRESS | | 9536 | 4 | 5442 | 7 | 139 | 8 | 13 | 1 | 528 | 2 | 5090 | 25 |

**I = Crashes; II = LN (Crashes)**
**C = Coefficient; T = T-Statistic; P = P-Value;**

Table 23. Summary of Results from Multivariate Analysis –

US-64 (Westbound Direction) in Martin County

| **Crash Type** | | **All Crashes** | | **Dry Crashes** | | **Wet Crashes** | | **Fatal Crashes** | | **Injury Crashes** | | **PDO Crashes** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type** | | I | II | I | II | I | II | I | II | I | II | I | II |
| **Step** | | 5 | 6 | 5 | 6 | 5 | 5 | | | 3 | 5 | 5 | 6 |
| **Constant** | | 44.76 | 5.315 | 8.932 | 4.931 | 0.779 | 1.617 | | | 8.249 | 2.083 | 34.11 | 4.839 |
| **Predictors** | **Parameter** | | | | | | | | | | | | |
| **Macrotexture** | **C** | -597.0 | -64.1 | | -59.5 | | -22.9 | | | -110.0 | -26.1 | -452.0 | -59.9 |
| | **T** | -1.9 | -7.5 | | -7.2 | | -2.8 | | | -1.8 | -2.8 | -1.8 | -6.7 |
| | **P** | 0.07 | 0.00 | | 0.00 | | 0.01 | | | 0.10 | 0.01 | 0.09 | 0.00 |
| **Million Vehicle Miles of Travel** | **C** | 742 | | 652 | | 306 | 20.8 | | | 232 | 20.7 | 518 | |
| | **T** | 2.9 | | 3.8 | | 5.6 | 3.2 | | | 4.1 | 2.8 | 2.5 | |
| | **P** | 0.01 | | 0.00 | | 0.00 | 0.00 | | | 0.00 | 0.01 | 0.02 | |
| **# Interchanges** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **# At-grade Intersections** | **C** | | | | | -1.5 | | | | | | | |
| | **T** | | | | | -2.4 | | | | | | | |
| | **P** | | | | | 0.03 | | | | | | | |
| **# Bridges** | **C** | | | | | | | | | -2.5 | | | |
| | **T** | | | | | | | | | -1.9 | | | |
| | **P** | | | | | | | | | 0.07 | | | |
| **# Culverts** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **# Grade Separated Interchanges** | **C** | | | 10.2 | | | | | | 3.7 | | | |
| | **T** | | | 1.8 | | | | | | 2.3 | | | |
| | **P** | | | 0.08 | | | | | | 0.03 | | | |
| **# Overhead Signs** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **S** | | 24.1 | 0.9 | 20.0 | 0.9 | 3.2 | 0.6 | | | 4.8 | 0.7 | 19.4 | 1.0 |
| **R Square** | | 64.8 | 70.7 | 60.6 | 69.0 | 76.8 | 73.9 | | | 79.2 | 71.1 | 59.6 | 66.0 |
| **R Square (Adj)** | | 61.6 | 69.4 | 57.0 | 67.6 | 74.7 | 71.6 | | | 75.1 | 68.4 | 55.9 | 64.5 |
| **PRESS** | | 16648 | 24 | 10680 | 22 | 315 | 11 | | | 789 | 14 | 10859 | 26 |

**I = Crashes; II = LN (Crashes)**
**C = Coefficient; T = T-Statistic; P = P-Value;**

MVMT was the only other variable that can be used to explain crashes on this corridor. However, except in case of wet crashes and injury crashes, MVMT is not predominant or significant enough to explain crashes when log-linear relation was considered.

T-Statistic is generally greater than 2 and P-Value is less than 0.05 for predictor variables selected in the final step. Also, it is observed that S and PRESS are low when logarithm of crashes was used. $R^2$ was generally higher when logarithm of crashes was used.

### *6.2.9 NC-42 (Eastbound Direction) in Johnston County*

Table 24 shows statistical parameters for models based on stepwise regression analysis for NC-42 (eastbound direction) in Johnston County. It can be seen from the table that pavement macrotexture was found to have a significant relationship with logarithm of all crashes, logarithm of dry crashes and logarithm of PDO crashes. The coefficient for pavement macrotexture is negative in all these cases indicating that crashes decrease with increase in pavement macrotexture.

While linear and log-linear relationship between crashes and MVMT was found to be more predominant, number of interchanges and at-grade intersections are two other variables with an impact on crashes. The presence of bridges was found to decrease crashes in some cases.

T-Statistic is generally greater than 2 and P-Value is less than 0.05 for predictor variables selected in the final step. Also, it is observed that S and PRESS are low and $R^2$ was higher for logarithm of crashes when compared to crashes.

### *6.2.10 NC-48 (Northbound Direction) in Nash County*

Table 25 shows statistical parameters for models based on stepwise regression analysis for NC-48 (Northbound direction) in Nash County. It can be seen from the table that pavement macrotexture was found to have a significant relationship with and without logarithm for all crash types except fatal crashes. The coefficient for pavement macrotexture is negative in all these cases indicating that crashes decrease with increase in pavement macrotexture.

Table 24. Summary of Results from Multivariate Analysis –

NC-42 (Eastbound Direction) in Johnston County

| **Crash Type** | | **All Crashes** | | **Dry Crashes** | | **Wet Crashes** | | **Fatal Crashes** | | **Injury Crashes** | | **PDO Crashes** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type** | | I | II | I | II | I | II | I | II | I | II | I | II |
| **Step** | | 5 | 4 | 5 | 4 | 3 | 3 | 6 | | 5 | 3 | 5 | 2 |
| **Constant** | | 0.449 | 3.488 | 0.137 | 3.084 | -0.483 | -0.059 | 0.083 | | -0.481 | 0.025 | 0.751 | 2.361 |
| **Predictors** | **Parameter** | | | | | | | | | | | | |
| **Macrotexture** | **C** | | -46.0 | | -42.0 | | | | | | | | -34.0 |
| | **T** | | -3.6 | | -3.5 | | | | | | | | -2.7 |
| | **P** | | 0.00 | | 0.00 | | | | | | | | 0.01 |
| **Million Vehicle Miles of Travel** | **C** | 1082 | 35 | 866 | 35 | | | | | 432 | 43 | 629 | |
| | **T** | 8.3 | 3.2 | 8.5 | 3.5 | | | | | 8.2 | 3.9 | 7.2 | |
| | **P** | 0.00 | 0.01 | 0.00 | 0.00 | | | | | 0.00 | 0.00 | 0.00 | |
| **# Interchanges** | **C** | | | | | 10.0 | 1.8 | | | | | | 1.7 |
| | **T** | | | | | 3.2 | 2.9 | | | | | | 2.4 |
| | **P** | | | | | 0.00 | 0.01 | | | | | | 0.03 |
| **# At-grade Intersections** | **C** | | | | | 1.7 | 0.4 | | | | 0.2 | | 0.3 |
| | **T** | | | | | 6.1 | 6.6 | | | | 1.9 | | 3.7 |
| | **P** | | | | | 0.00 | 0.00 | | | | 0.07 | | 0.00 |
| **# Bridges** | **C** | | | | | -5.1 | -1.0 | | | | -0.6 | | -0.9 |
| | **T** | | | | | -3.3 | -3.2 | | | | -1.8 | | -2.7 |
| | **P** | | | | | 0.00 | 0.01 | | | | 0.08 | | 0.02 |
| **# Culverts** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **# Grade Separated Interchanges** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **# Overhead Signs** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **S** | | 13.8 | 0.7 | 10.8 | 0.7 | 2.9 | 0.6 | 0.3 | | 5.6 | 0.7 | 9.2 | 0.6 |
| **R Square** | | 75.8 | 83.2 | 76.5 | 84.2 | 71.6 | 74.3 | 0.0 | | 75.2 | 80.3 | 70.2 | 85.7 |
| **R Square (Adj)** | | 74.7 | 81.6 | 75.4 | 82.7 | 67.4 | 70.5 | 0.0 | | 74.0 | 77.4 | 68.8 | 82.6 |
| **PRESS** | | 4910 | 13 | 3036 | 11 | | | 2 | | 811 | 13 | 2183 | |

**I = Crashes; II = LN (Crashes)**
**C = Coefficient; T = T-Statistic; P = P-Value;**

Table 25. Summary of Results from Multivariate Analysis –

NC-48 (Northbound Direction) in Nash County

| **Crash Type** | | **All Crashes** | | **Dry Crashes** | | **Wet Crashes** | | **Fatal Crashes** | | **Injury Crashes** | | **PDO Crashes** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type** | | I | II | I | II | I | II | I | II | I | II | I | II |
| **Step** | | 5 | 4 | 5 | 4 | 6 | 6 | | | 5 | 6 | 3 | 4 |
| **Constant** | | 43.43 | 7.16 | 34.4 | 6.744 | 7.145 | 2.336 | | | 9.261 | 3.543 | 22.67 | 6.376 |
| **Predictors** | **Parameter** | | | | | | | | | | | | |
| **Macrotexture** | **C** | -478.0 | -74.0 | -379.0 | -70.9 | -76.0 | -25.7 | | | -104.0 | -39.4 | -244.0 | -67.3 |
| | **T** | -10.1 | -7.3 | -10.7 | -7.1 | -4.6 | -5.1 | | | -3.0 | -8.0 | -3.2 | -8.1 |
| | **P** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | 0.01 | 0.00 | 0.01 | 0.00 |
| **Million Vehicle Miles of Travel** | **C** | | -65 | | -61 | | | | | | | 462 | -58 |
| | **T** | | -2.3 | | -2.2 | | | | | | | 1.9 | -2.5 |
| | **P** | | 0.04 | | 0.05 | | | | | | | 0.10 | 0.03 |
| **# Interchanges** | **C** | 15.6 | 0.6 | 15.4 | 0.7 | | | | | | | 12.1 | 0.7 |
| | **T** | 4.8 | 1.9 | 6.3 | 2.1 | | | | | | | 5.0 | 2.7 |
| | **P** | 0.00 | 0.09 | 0.00 | 0.06 | | | | | | | 0.00 | 0.02 |
| **# At-grade Intersections** | **C** | | | | | | | | | 0.6 | | -0.9 | |
| | **T** | | | | | | | | | 2.3 | | -2.2 | |
| | **P** | | | | | | | | | 0.04 | | 0.05 | |
| **# Bridges** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **# Culverts** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **# Grade Separated Interchanges** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **# Overhead Signs** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **S** | | 3.9 | 0.3 | 2.9 | 0.3 | 1.5 | 0.5 | | | 2.0 | 0.4 | 2.4 | 0.3 |
| **R Square** | | 94.9 | 96.0 | 96.0 | 96.0 | 63.9 | 68.4 | | | 85.1 | 84.1 | 96.8 | 96.9 |
| **R Square (Adj)** | | 94.0 | 94.8 | 95.3 | 94.7 | 60.9 | 65.8 | | | 82.4 | 82.8 | 95.3 | 95.9 |
| **PRESS** | | 222 | 2 | 135 | 2 | 36 | 3 | | | 69 | 3 | 145 | 1 |

**I = Crashes; II = LN (Crashes)**
**C = Coefficient; T = T-Statistic; P = P-Value;**

MVMT and the number of interchanges are the only other variables that tend to have an impact on crashes. Increase in MVMT generally tends to decrease the number of crashes whereas the number of interchanges tends to increase the number of crashes on this corridor.

T-Statistic is generally greater than 2 and P-Value is less than 0.05 for predictor variables selected in the final step. Also, it is observed that S and PRESS are low and $R^2$ was higher when logarithm of crashes was used than when compared to crashes.

### *6.2.11 Highways*

Table 26 shows statistical parameters for models based on stepwise regression analysis for all highways. It can be seen from the table that pavement macrotexture was found to have a significant relationship with logarithm of all crash types except fatal crashes. The coefficient for pavement macrotexture is negative in all these cases indicating that crashes decrease with increase in pavement macrotexture.

MVMT and the number of interchanges were found to be significant variables in case of linear relationship whereas the number of at-grade intersections is more predominant in case of log-linear models.

T-Statistic is generally greater than 2 and P-Value is less than 0.05 for predictor variables selected in the final step. Also, it is observed that S and PRESS are low when logarithm of crashes was used. However, $R^2$ was higher when crashes were used to develop models than when compared to logarithm of crashes.

### *6.2.12 Highways and I-40 in Pender County*

Table 27 shows statistical parameters for models based on stepwise regression analysis for all highways and I-40 in Pender County. It can be seen from the table that pavement macrotexture was found to have a significant relationship with wet crashes, fatal crashes and logarithm of all crash types (including wet and fatal crashes). The coefficient for pavement macrotexture is negative in all these cases indicating that crashes decrease with increase in pavement macrotexture.

Table 26. Summary of Results from Multivariate Analysis – Highways

| Crash Type | | All Crashes | | Dry Crashes | | Wet Crashes | | Fatal Crashes | | Injury Crashes | | PDO Crashes | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type** | | I | II | I | II | I | II | I | II | I | II | I | II |
| **Step** | | 5 | 5 | 5 | 5 | 4 | 5 | 4 | 5 | 4 | 3 | 4 | 5 |
| **Constant** | | -2.867 | 5.666 | -1.166 | 5.303 | -0.35 | 2.176 | 0.017 | -0.017 | -0.368 | 2.668 | -0.555 | 4.914 |
| **Predictors** | **Parameter** | | | | | | | | | | | | |
| **Macrotexture** | **C** | | -59.9 | | -56.9 | | -24.3 | | | | -29.4 | | -52.0 |
| | **T** | | -7.6 | | -7.4 | | -3.9 | | | | -4.1 | | -6.5 |
| | **P** | | 0.00 | | 0.00 | | 0.00 | | | | 0.00 | | 0.00 |
| **Million Vehicle Miles of Travel** | **C** | 1785 | | 1390 | | 432 | 13.8 | 4.1 | | 561 | 10.5 | 1697 | 9.2 |
| | **T** | 18.6 | | 19.5 | | 12.0 | 5.0 | 2.0 | | 18.2 | 2.3 | 10.2 | 2.6 |
| | **P** | 0.00 | | 0.00 | | 0.00 | 0.00 | 0.06 | | 0.00 | 0.03 | 0.00 | 0.01 |
| **# Interchanges** | **C** | -14.5 | | -15.6 | | | | | | -7.9 | | -12.0 | |
| | **T** | -1.8 | | -2.6 | | | | | | -4.0 | | -1.7 | |
| | **P** | 0.08 | | 0.02 | | | | | | 0.00 | | 0.10 | |
| **# At-grade Intersections** | **C** | | 0.1 | | 0.1 | -0.9 | | | 0.0 | | 0.1 | -2.2 | |
| | **T** | | 2.2 | | 2.3 | -2.9 | | | 3.3 | | 2.0 | -2.0 | |
| | **P** | | 0.03 | | 0.03 | 0.01 | | | 0.00 | | 0.05 | 0.06 | |
| **# Bridges** | **C** | | | | | -1.8 | | 0.2 | | -2.3 | | | |
| | **T** | | | | | -2.5 | | 2.7 | | -3.3 | | | |
| | **P** | | | | | 0.02 | | 0.01 | | 0.00 | | | |
| **# Culverts** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **# Grade Separated Interchanges** | **C** | | | | | | | -0.4 | -0.1 | | -0.3 | | |
| | **T** | | | | | | | -3.9 | -2.8 | | -1.9 | | |
| | **P** | | | | | | | 0.00 | 0.01 | | 0.07 | | |
| **# Overhead Signs** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **S** | | 21.9 | 0.8 | 16.4 | 0.7 | 5.4 | 0.6 | 0.4 | 0.1 | 5.3 | 0.6 | 17.5 | 0.7 |
| **R Square** | | 96.0 | 88.5 | 96.1 | 88.2 | 93.4 | 87.2 | 37.9 | 25.9 | 96.7 | 89.2 | 95.2 | 87.9 |
| **R Square (Adj)** | | 95.7 | 57.8 | 95.8 | 87.5 | 92.7 | 86.4 | 31.9 | 21.3 | 96.4 | 87.8 | 94.8 | 87.1 |
| **PRESS** | | 21405 | 22 | 11026 | 21 | 1398 | 12 | 8 | 1 | 1257 | 14 | 14815 | 20 |

**I = Crashes; II = LN (Crashes)**
**C = Coefficient; T = T-Statistic; P = P-Value;**

Table 27. Summary of Results from Multivariate Analysis – Highways and I-40 in Pender County

| Crash Type | | All Crashes | | Dry Crashes | | Wet Crashes | | Fatal Crashes | | Injury Crashes | | PDO Crashes | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type** | | I | II | I | II | I | II | I | II | I | II | I | II |
| **Step** | | 6 | 5 | 6 | 5 | 4 | 5 | 6 | 5 | 4 | 5 | 6 | 5 |
| **Constant** | | -0.646 | 5.849 | -1.251 | 5.172 | 17.3 | 2.728 | 0.675 | 0.335 | -0.188 | 3.458 | -0.462 | 4.939 |
| **Predictors** | **Parameter** | | | | | | | | | | | | |
| **Macrotexture** | **C** | | -62.5 | | -55.4 | -211.0 | -31.7 | -7.8 | -4.1 | | -38.9 | | -53.1 |
| | **T** | | -8.9 | | -7.8 | -3.3 | -5.3 | -2.2 | -2.7 | | -6.4 | | -7.5 |
| | **P** | | 0.00 | | 0.00 | 0.00 | 0.00 | 0.04 | 0.01 | | 0.00 | | 0.00 |
| **Million Vehicle Miles of Travel** | **C** | 1177 | | 916 | | 121 | 2.61 | | -0.86 | 283 | | 883 | |
| | **T** | 35.4 | | 40.0 | | 4.3 | 3.4 | | -1.8 | 17.6 | | 35.1 | |
| | **P** | 0.00 | | 0.00 | | 0.00 | 0.00 | | 0.08 | 0.00 | | 0.00 | |
| **# Interchanges** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **# At-grade Intersections** | **C** | 3.5 | 0.1 | 2.7 | 0.1 | | 0.1 | | | 1.8 | 0.1 | 2.0 | 0.1 |
| | **T** | 3.7 | 2.8 | 4.1 | 3.1 | | 3.0 | | | 6.0 | 4.1 | 2.8 | 3.1 |
| | **P** | 0.00 | 0.01 | 0.00 | 0.00 | | 0.01 | | | 0.00 | 0.00 | 0.01 | 0.00 |
| **# Bridges** | **C** | | | | | | | | | -3.9 | | | |
| | **T** | | | | | | | | | -2.7 | | | |
| | **P** | | | | | | | | | 0.01 | | | |
| **# Culverts** | **C** | | | | 0.2 | 7.3 | | 0.2 | 0.2 | | 0.3 | | 0.3 |
| | **T** | | | | 1.8 | 2.4 | | 2.6 | 2.4 | | 2.4 | | 2.1 |
| | **P** | | | | 0.08 | 0.03 | | 0.01 | 0.02 | | 0.02 | | 0.05 |
| **# Grade Separated Interchanges** | **C** | | | | | 3.4 | | | | 3.4 | | | |
| | **T** | | | | | 2.4 | | | | 1.8 | | | |
| | **P** | | | | | 0.02 | | | | 0.09 | | | |
| **# Overhead Signs** | **C** | | | | | | | | | | | | |
| | **T** | | | | | | | | | | | | |
| | **P** | | | | | | | | | | | | |
| **S** | | 28.4 | 0.8 | 19.6 | 0.7 | 8.0 | 0.6 | 0.5 | 0.2 | 7.2 | 0.6 | 21.5 | 0.7 |
| **R Square** | | 98.5 | 89.6 | 98.8 | 90.1 | 96.5 | 88.3 | 36.5 | 32.5 | 98.5 | 89.5 | 98.5 | 89.8 |
| **R Square (Adj)** | | 98.4 | 89.0 | 98.8 | 89.2 | 96.0 | 87.2 | 32.7 | 26.2 | 98.3 | 88.6 | 98.4 | 88.9 |
| **PRESS** | | 44984 | 24 | 17090 | 21 | 12250 | 17 | 12 | 2 | 4343 | 16 | 26240 | 21 |

**I = Crashes; II = LN (Crashes)**
**C = Coefficient; T = T-Statistic; P = P-Value;**

While MVMT is significant in case of models based on linear relationships, the number of interchanges (which do not exist on most considered corridors) was not dominant in any model. The number of at-grade intersections followed by the number of culverts was found to be related to crashes and its types in most cases.

T-Statistic is generally greater than 2 and P-Value is less than 0.05 for predictor variables selected in the final step. Also, it is observed that S and PRESS are low when logarithm of crashes was used. However, $R^2$ was higher when crashes were used than when compared to logarithm of crashes.

Linear or log-linear relationship between fatal crashes or wet crashes and pavement macrotexture can be observed in this case as the sample size (number of fatal crashes) is high when data for corridors was combined.

### *6.2.13 Multivariate Analysis – Summary of Results*

Results indicate that a reasonably strong relationship exists between pavement macrotexture and crashes. Statistical parameters such as S and PRESS indicate that log-linear models can explain the relationship better than linear models. The coefficient for pavement macrotexture in log-linear models is always negative indicating crashes increase as pavement macrotexture decreases.

The $R^2$ and $R^2$ (Adjusted) values for a crash type for a corridor in case of multivariate analysis are generally greater than $R^2$ and $R^2$ (Adjusted) values for the same crash type and corridor in case of bivariate analysis. This indicates that pavement macrotexture alone cannot explain crashes on a corridor. The relationship could be better explained by considering variables such as MVMT, number of interchanges, number of bridges, number of culverts, number of grade separated interchanges or number of at-grade intersections in addition to pavement macrotexture.

The statistical parameters in case of fatal crashes on individual study corridors indicate a relatively weak or no relationship between pavement macrotexture and fatal crashes. However, a significant relationship between pavement macrotexture and fatal crashes was observed when data were combined for highways and I-40 in Pender County. Thus, the weak relationship between pavement macrotexture and fatal crashes in case of individual corridors could be attributed to fewer numbers of fatal crashes (sample size) on each corridor. Table 28 summarizes confidence level with which the relationship between pavement macrotexture and crashes can be explained for each study corridor and scenario.

Table 28. Relationship Between Pavement Macrotexture and Crashes – Summary Based on Confidence Level from Multivariate Analysis

| Corridor | Direction by Lane | Crashes Vs. Macrotexture | | | | | | LN of Crashes Vs. Macrotexture | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | All | Dry | Wet | Fatal | Injury | PDO | All | Dry | Wet | Fatal | Injury | PDO |
| I-40 in Durham | Eastbound - Outside Lane | | | | | | | 100.0 | 99.9 | | | 100.0 | 99.9 |
| | Eastbound - Inside Lane | | | | | | | 99.8 | 99.7 | | | 90.6 | 99.2 |
| | Westbound - Outside Lane | 99.7 | 99.7 | | | 99.8 | 99.7 | 97.5 | 96.8 | | | | 94.4 |
| | Westbound - Inside Lane | 99.9 | | 97.9 | | 93.6 | | 99.7 | 99.4 | | | 93.6 | 98.6 |
| I-40 in Pender | Eastbound | 98.5 | | 96.7 | 97.5 | | 98.0 | 97.4 | 99.6 | 99.8 | 97.5 | 98.8 | 98.2 |
| | Westbound | | | | | | | 98.2 | 99.2 | | | | 99.2 |
| US-64 in Martin | Eastbound | 97.8 | 97.3 | | 95.2 | 99.3 | 97.6 | 99.9 | | 98.9 | | | |
| | Westbound | 92.8 | | | | 90.4 | 91.1 | 100.0 | 100.0 | 99.0 | | 100.0 | 99.0 |
| NC-42 in Johnston | Eastbound | | | | | | | 99.8 | 99.8 | | | | 98.6 |
| NC-48 in Nash | Northbound | 100.0 | 100.0 | 99.9 | | 98.7 | 98.9 | 100.0 | 100.0 | 100.0 | | 100.0 | 100.0 |
| Highways | | | | | | | | 100.0 | 100.0 | 100.0 | | 100.0 | 100.0 |
| Highways and I40Pender | | | | 99.7 | 96.4 | | | 100.0 | 100.0 | 100.0 | 98.9 | 100.0 | 100.0 |

# CHAPTER 7: CONCLUSIONS AND SCOPE FOR FUTURE WORK

The relationship between pavement macrotexture and crash incidences on selected NC routes is studied and presented in this report. Bivariate and multivariate statistical analysis was used to study the relationship and support the general notion that the number of crashes increase as pavement macrotexture decrease on roads.

Results from bivariate analysis indicate a reasonably strong relationship between pavement macrotexture and crashes. Both linear and log-linear relationships were tested. The coefficient for pavement macrotexture is negative in all the cases and corridors considered indicating that crashes increase when pavement macrotexture is decreased.

The relationship between pavement macrotexture and crashes in comparison to other predictor variables such as million vehicle miles of travel (as a function of traffic volume and length), the number of interchanges, the number of bridges, the number of culverts, the number of grade separated interchanges, the number of at-grade intersections, and the number of overhead signs was studied using multivariate analysis. Results, in general, indicate that pavement macrotexture has a significant impact on crashes on roads. Relationship between dry crashes, wet crashes, fatal crashes, injury crashes and PDO crashes and pavement macrotexture was also observed. The relationship could be better explained when log-linear models are used.

Scatter plots show that pavement macrotexture greater than 0.06” would help decrease crashes and improve safety on roads. Figures 25 and 26 developed using multivariate statistical models for highways and highways and I-40 in Pender County supports the observations from scatter plots that pavement macrotexture greater than 0.06” and typically less than 0.12” could help improve safety on roads.

## 7.1 Scope for Future Work and Implementation Plan

While I-40 in Durham County is tined concrete pavement, all other corridors considered in this study are asphalt pavements. The study corridors, other than I-40 in Durham County, have very low pavement macrotexture values (typically in the range of 0.03” and 0.06”). One possible reason could be that these corridors were not repaved for more than a decade. Vehicular traffic (in particular, trucks) on these corridors during this period may have resulted in low pavement macrotexture values. Though this did not have a big impact on the overall relationship and results, further investigation by considering more asphalt pavements is needed to study the impact of traffic volume/mix and years since last paved to better understand the relationship between pavement macrotexture and crashes.

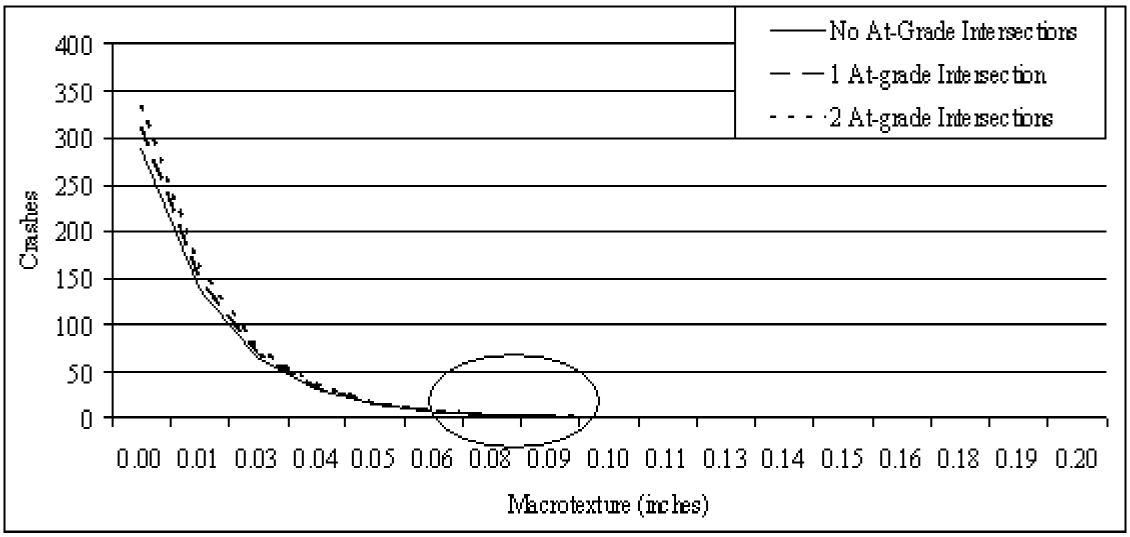



Figure 25. Selection of Threshold Values Based on Statistical Analysis for Highways

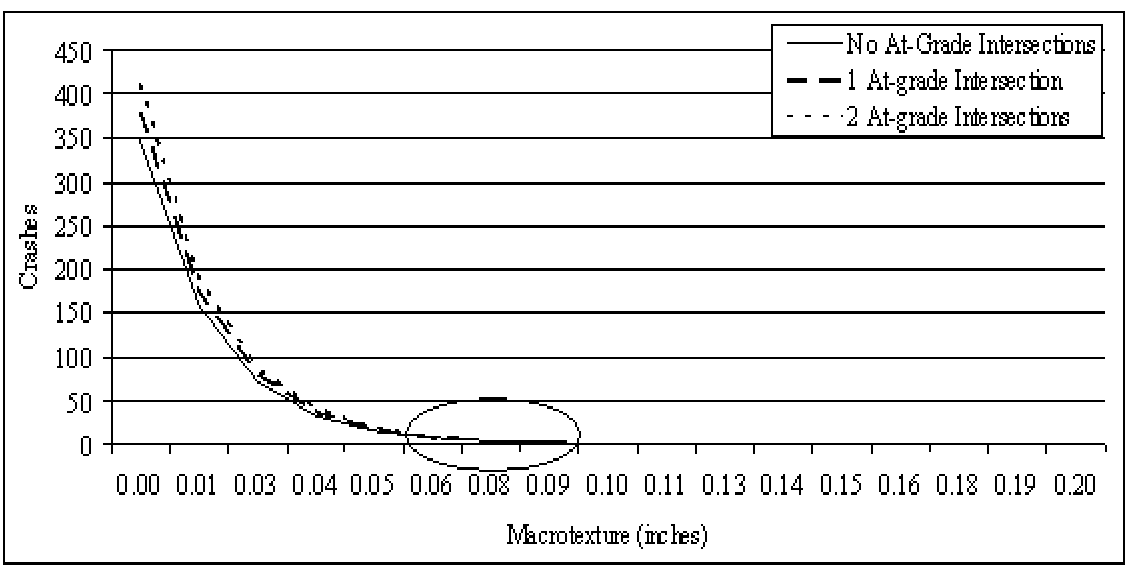



Figure 26. Selection of Threshold Values Based on Statistical Analysis for Highways and I-40 in Pender County

Additional data pertaining to concrete pavements should also be considered and analyzed to study and confirm the high pavement macrotexture values on tined concrete pavements (such as the values obtained on I-40 in Durham County in this study). This will not only help understand the difference in pavement macrotexture between concrete and asphalt pavements but also help if trends observed in this study extend over a broader range of concrete and asphalt pavements.

While targeting a high pavement macrotexture value (such as 0.06”) for implementation is debatable and not within the scope of this project, NCDOT should consider repaving 3 test corridors with currently low macrotexture values and high number of crashes to a high macrotexture range (say, 0.06” to 0.08”) and monitor them for 2 years. Data such as profile elevation, crashes, traffic volumes and speed collected “before” and “after” repaving to increase pavement macrotexture would help quantify potential cost benefits due to implementation.

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