Development of Roughness Thresholds for the Preventive Maintenance of Pavements based on Dynamic Loading Considerations and Damage Analysis

Karim Chatti, Ph.D.
Doseung Lee, M.S.
Gilbert Y. Baladi, Ph.D., P.E.

PRCE

Michigan State University
Pavement Research Center of Excellence

Final Report – Volume I
June 2001

TESTING AND RESEARCH SECTION
CONSTRUCTION AND TECHNOLOGY DIVISION
RC - 1396 - FINAL REPORT VOLUME I

Technical Report Documentation Page

1. Report No. RC-1396	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Development of Roughness Thresholds for the Preventive Maintenance of Pavements based on Dynamic Loading Considerations and Damage Analysis		5. Report Date June 2001
7. Author(s) Karim Chatti, Ph.D. Doseung Lee, M.S. Gilbert Y. Baladi, Ph.D., P.E.		6. Performing Organization Code
9. Performing Organization Name and Address **PAVEMENT RESEARCH CENTER OF EXCELLENCE** Michigan State University Department of Civil and Environmental Engineering East Lansing, Michigan 48824-1226		8. Performing Org Report No.
12. Sponsoring Agency Name and Address Michigan Department of Transportation Construction and Technology Division P.O. Box 30049 Lansing, MI 48909		10. Work Unit No. (TRAIS) 11. Contract/Grant No. 94-1699
15. Supplementary Notes		13. Type of Report & Period Covered Final Report (10/98 – 12/00) 14. Sponsoring Agency Code

16. Abstract

The objective of this study was to investigate the interaction between surface roughness, dynamic truck loading and pavement damage for the purpose of determining roughness thresholds. These thresholds would be used in the pavement management system as an early warning for preventive maintenance action. This was done by testing the hypothesis that there is a certain level of roughness (roughness threshold-values) at which a sharp increase in dynamic load occurs, thus causing an acceleration in pavement damage accumulation.

The research was successful at validating the above hypothesis by: 1) Identifying empirical relationships between roughness and distress using current indices from in-service pavements. 2) Developing similar relationships between surface roughness and theoretical pavement damage using the mechanistic approach.

The above relationships allowed for determining critical ranges of RQI, at which distress and theoretical pavement damage accelerate. Reasonable agreement was obtained between theoretically-derived and empirically-derived ranges. However, these RQI-ranges were too wide to be adopted at the project level. It was therefore concluded that the RQI was not suitable for predicting dynamic truck loads at the project level, i.e., for a specific pavement profile.

Consequently, a new roughness index, called the Dynamic Load Index (DLI), was developed for the purpose of identifying "unfriendly" pavement profiles from a dynamic truck loading aspect. The new index was used to develop tables showing the predicted life extension that would be achieved by smoothing a pavement section with a given remaining service life (RSL) for different DLI levels. These tables can be used to decide when smoothing action needs to be taken in order to get a desired life extension for a particular project. Comparison with RSL-values derived using actual distress growth over time from in-service pavements allowed for determining the optimal range of DLI-values that would lead to the desired life extension upon smoothing the pavement surface. The results showed that such preventive maintenance smoothing action is best suited for rigid pavements.

17. Key Words: ride quality, distress, roughness threshold, dynamic axle loads, dynamic load index, preventive management, remaining service life, life extension, optimal timing		18. Distribution Statement No restrictions. This document is available to the public through the Michigan Department of Transportation.	
19. Security Classification (report) Unclassified	20. Security Classification (Page) Unclassified	21. No of Pages	22. Price

Form DOT F 1700.7 (8-72)

DISCLAIMER

This document is disseminated under the sponsorship of the Michigan Department of Transportation (MDOT) in the interest of information exchange. MDOT assumes no liability for its contents or use thereof.

The contents of this report reflect the views of the contracting organization, which is responsible for the accuracy of the information presented herein. The contents may not necessarily reflect the views of MDOT and do not constitute standards, specifications, or regulations.

Table of Contents

List of Tables

List of Figures

EXECUTIVE SUMMARY

An increase in pavement roughness leads to higher dynamic axle loads in certain portions of the road. This amplification in the load magnitude can lead to a tangible acceleration in pavement distress, which in turn makes the pavement rougher. The objective of this study is to investigate this interaction by analyzing the relationship between truck axle loads, surface roughness and pavement damage for the purpose of determining roughness thresholds, which would be used in the pavement management system as an early warning for preventive maintenance action.

The research in this study is based on the hypothesis that there is a certain level of roughness (roughness threshold-value) at which a sharp increase in dynamic load occurs, thus causing acceleration in pavement damage accumulation. This hypothesis was tested using both empirical and mechanistic analyses. In the empirical approach, the analysis consisted in determining the relationship between the Ride Quality Index (RQI) and the Distress Index (DI) from several hundred sections. In the mechanistic approach, actual surface profiles were used to generate dynamic axle loads using a truck simulation program. The power law of pavement damage was then used to determine the damage caused by dynamic loads relative to that caused by static loads. The corresponding reduction in pavement life was then calculated to predict the extension of pavement life that would likely occur if the pavement surface would be smoothed.

A new roughness index that uses surface profile characteristics that are known to "excite" trucks was developed. This index better represents the dynamic truck axle loads than the RQI or the IRI, without the need to run a truck simulation program. This new Dynamic Load Index (DLI) was then correlated to the 95th percentile dynamic load, which was used to calculate the relative pavement damage and the corresponding reduction in pavement life. Finally, tables showing the predicted extension in pavement life for different combinations of Remaining Service Life (RSL) and DLI were generated. These tables are intended to be used as a tool for planning preventive maintenance actions aimed at minimizing dynamic truck loads by smoothing the pavement surface.

Correlating Surface Roughness, Dynamic Loading and Pavement Distress

The relationship between load and distress is complex, and is not well understood to this date. The variability in pavement materials, environmental and traffic factors, coupled with errors in field measurements and the subjectivity of the field distress surveys make it extremely difficult to relate roughness and dynamic loading to the accumulation of pavement distress in in-service pavements. Furthermore, some distresses are mainly material- or environment- related. To show how one could use roughness and distress data together for the purpose of discerning between cases of load-related distress accumulation and other non-load-related distress accumulation, several analyses on distress and roughness data from MDOT PMS files were done.

For this phase of the research study, the MDOT Technical Advisory Group (TAG) was given the task of selecting ten sites with known performance records and having exhibited some distress in the time period between 1992 and 1997. Five of the ten sites were rigid pavements, three were flexible pavements with rubblized concrete bases, and two were composite pavements. DI and RQI data as well as road surface profiles were obtained from the MDOT PMS database. DI values were available for 1993, 1995 and 1997, whereas RQI values and road profiles were available for the period between 1992 and 1996. The DI and RQI data were available for 0.1-mile sections. Surface profile data were converted to ASCII files containing surface elevations at 3-in intervals. In addition, detailed distress data in the form of distress type, severity and extent was also available to the research team at 10-ft intervals. The data were converted to Distress Points (DP).

Correlation between Dynamic Loads from Different Axles and Trucks

This analysis was aimed at investigating the spatial repeatability of dynamic loads from different truck axles. For this, the TruckSim™ program was used to generate dynamic axle loads from three truck types: Two- and 3-axle single unit trucks and a 5-axle tractor semi-trailer. These trucks were selected because they constitute more than 85% of all trucks using the main trunkline roads in the state of Michigan. Coefficients of correlation (ρ) between the spatial variations for each axle load and that for a reference axle load (2nd axle load in 5-axle semi-trailer) were determined. The results show variable degrees of correlation among different axles. The best correlations are among the drive axles from the three trucks while the worst is with the rear axle of the tractor semi-trailer, indicating that the trailer is out-of phase with the tractor. The correlation between aggregate axle loads (accumulation of loads at a fixed point in the pavement) for the different trucks is strong with coefficients of correlation higher than 0.77. Previous research (Cole, 1990) has shown that a ρ-value of 0.707 or higher is indicative of good spatial repeatability. Aggregate axle loads for each truck and the reference axle load also showed very good correlation with values around 0.7. This indicates that the reference axle can be used to represent the aggregate load from all trucks. Based on the findings of this analysis, the 2nd axle load of the 5-axle semi-trailer was used for the remainder of the analysis.

Distress and Roughness Profiles

DI and RQI data for all ten sites were normalized with respect to their respective threshold values of 40 and 70, and plotted along the longitudinal direction. The threshold values correspond to the trigger values for pavement rehabilitation, as categorized by the MDOT PMS. These plots which were generated for 1993, 1995 and 1997 give an overall view of DI and RQI levels for the entire project length in a given site. Comparison of DI and RQI profiles allows for identifying sections of high distress and/or high roughness levels.

Distress, Roughness and Dynamic Loading Trends with Time

From each site, four 0.1-mile sections were selected for further analysis. These sections included cases of "high distress - high roughness", "high distress - low roughness" and "low distress - high roughness." For each 0.1-mile section, IRI values were calculated using the RoadRuf computer program (developed by UMTRI). Normalized DI, RQI and IRI, and DLC values for each subsection were plotted at consecutive years. These plots show whether the DI increase occurred at a high or a low level of roughness. Combining this information with 'distress and roughness profiles' allows for discerning dynamic load-related from non-load-related distress accumulation.

Distress Point and Dynamic Loading Spatial Distribution

To further confirm whether the distress is load-related or not, one can plot the distribution of Distress Points (DP) along the 0.1-mile long section against that of the dynamic load (DL). Both DP and DL values were normalized with respect to their respective 95th percentile value, which should represent the more severe cases of distress accumulation and dynamic load amplification, respectively. Comparison of dynamic-load and distress-point profiles along the length of a given pavement section enabled the assessment of the reasonableness of the ρ-values relating the two profiles. The results showed that a reasonably good match between load and distress profiles is possible with relatively low ρ-values (between 0.25 and 0.5) whereas a ρ-value that is less than 0.2 is indicative of a poor match. A higher ρ-value indicates dynamic load-related distress accumulation, and a lower ρ-value indicates that the distress accumulation is not primarily related to dynamic loading.

Network-Level Relationships between Ride Quality and Distress Indices

To confirm the hypothesis that there is a critical roughness value at which dynamic loading significantly increases causing acceleration in pavement damage, the relationship between the distress index (DI) and the roughness index (RQI) was sought using measured distress and roughness data from the MDOT PMS database.

For this analysis, three independent data sets (for a total of 97 projects) were selected from the Michigan pavement network. The first data set has thirty-seven pavement projects: Ten projects with known performance records and having exhibited some distress, and twenty-seven projects where preventive maintenance activities were done during 1997 and 1998 were selected. Thirteen of the thirty-seven sites were rigid; fifteen were flexible; and nine were composite pavements. The second and third data sets were selected randomly from the Michigan pavement network. Each data set has thirty projects evenly divided between rigid, composite and flexible pavements. These selected projects cover a wide range in pavement age and traffic volume. The length of these pavement projects varies from 1.5 to 23 miles with an average project length of 7.4 miles. Their ages range from 1 to 39 years. The corresponding commercial daily traffic volume ranges from 70 to 12300.

Analysis on Load-Related Distress Types

An attempt to isolate dynamic load-related distress types was made using the three independent data sets. For this analysis, several subsections having the same range in DI level but different RQI levels were selected. For each selected section, distress points of each distress type were calculated. In this calculation, transverse and longitudinal cracks were divided into two types: i) cracks having no associated distress; and ii) cracks with associated distress such as spalling. Associated distress is a distress occurring around a main distress, and is used to define subsequent deterioration of the main distress in MDOT PMS.

Proportions of distress points of each distress type were plotted for relatively rough and relatively smooth subsections at each DI level. The first data set showed that for rigid pavements, transverse cracks with associated distress, transverse joint deterioration, delamination and patch deterioration appeared to be dominant in relatively rough sections at most DI levels, while transverse cracks without associated distress were dominant in relatively smooth sections at most DI levels. For flexible and composite pavements, transverse cracks with associated distress appeared to be dominant in relatively rough sections. These results seemed to indicate that it was possible to discern between dynamic-load-related distress types and other distresses. However, further analysis conducted using the second and third independent data sets did not support this conclusion. The second and third data sets showed that for rigid pavements, unlike the results from original data set, transverse cracks with associated distress were dominant in relatively smooth sections at high DI levels, while transverse joint deterioration was dominant in relatively smooth sections at low DI levels. For composite pavements, there was no major difference in proportions of transverse cracks with associated distress between rough and smooth sections at high DI levels. For flexible pavements, transverse cracks with associated distress were dominant in smooth sections and longitudinal cracks were dominant in rough sections at high DI levels. These results do not agree with those from the original data set. Therefore, it was concluded that it was not always possible to isolate dynamic load-related distress types from non-load-related distress types. Accordingly, it was decided that the overall DI would be used to develop the relationship between roughness and distress.

Relationship between DI and RQI

Using the three data sets, DI-RQI relationships were obtained. Rigid pavements had the highest R^2-values: $R^2 = 0.488$, 0.699 and 0.731 for the first, second and third data sets, respectively. Flexible pavements had the lowest R^2-values (0.311, 0.448 and 0.507), and composite pavements had R^2-values in-between (0.522, 0.511 and 0.603). From these relationships, critical RQI values where the second derivative of the DI-RQI function is maximal were obtained. The three data sets gave critical RQI-values of 57, 54 and 57 for rigid pavements, and 44, 48 and 42 for composite pavements. For Flexible pavements, critical RQI-values were found to be 45, 40 and 44; however, these values are considered to be unreliable because of the high scatter in the flexible pavement distress data.

The results indicate that rigid pavements have higher critical RQI-values than composite and flexible pavements. This seems to be caused by the following three factors: First, the mechanisms of how the pavement surface becomes rough with time are different in rigid and flexible (or composite) pavements. For rigid pavements, the pavement surface becomes rough because of faulting, curling and warping. These distresses can happen without the existence of cracks. This means that the pavement surface can be rough without the existence of cracks, i.e., a rigid pavement can have high RQI-values without an increase in DI-value under the MDOT distress index pointing system. For flexible pavements, on the other hand, the pavement surface becomes rough mainly because of cracks. This difference makes rigid pavements exhibit higher critical RQI-values. The second factor could be the initial smoothness (or roughness) of a newly constructed or rehabilitated pavement. Generally, the initial roughness for rigid pavements is higher than that for flexible pavements because of the existence of joints. This high initial roughness may cause the critical RQI-values to shift up to a higher value. Finally, the third factor could be the material behavior. Portland cement concrete is stronger than asphalt concrete; therefore, rigid pavements should be able to sustain higher dynamic axle loads than do flexible pavements. All the above-cited factors may lead to a higher critical RQI-value for rigid pavements.

Network-Level Relationships between Ride Quality Index and Dynamic Load

In this analysis, the mechanistic approach was used to investigate the existence of a critical RQI-value where pavement damage sharply increases. This was done by relating dynamic loading and theoretical pavement damage to RQI. Three hundred thirty three (333) 0.1-mile sections for each roughness level (RQI=30, 40, 50, 60, 70, and higher than 80) were selected randomly from the 37 projects used in the first data set. Dynamic axle load profiles (2nd axle of the tractor-semi-trailer) were generated along each 0.1-mile section using TruckSim™. From these dynamic axle-load profiles, DLC (Dynamic Loading Coefficient) and the 95th percentile axle load were calculated and plotted against the corresponding RQI-values. The data were fit to fourth-order polynomial curves, with the resulting R^2-values ranging from 0.85 to 0.95. The DLC-RQI curves had slightly better R^2-values ($R^2 = 0.91$ to 0.95) than the 95th percentile axle load curves ($R^2 = 0.85$ to 0.93), with the highest values being for rigid pavements and the lowest values for flexible pavements.

Using the 4th power law, the relative damage from the 95th percentile dynamic load at different RQI levels was calculated. The corresponding reduction in pavement life for each roughness level was calculated using Miner's hypothesis. Based on these relationships, the critical RQI-values where pavement damage sharply increases were determined for rigid, flexible and composite pavements. The lower bound for the critical RQI-value was taken as the minimum slope of the curve, beyond which the rate of damage or reduction in pavement life starts increasing. These values were equal to 61, 50 and 47 for rigid, composite and flexible pavements, respectively. The upper bound for the critical RQI-value was taken as the maximum acceleration of the curve, at which the acceleration in damage or the rate of increase in the reduction of pavement life is highest. These values were equal to 77, 70 and 66 for rigid, composite and flexible pavements, respectively. The lower bound value corresponds to the point at which the reduction in pavement life starts to accelerate, whereas the upper bound value corresponds to where the acceleration in pavement damage is highest. The optimal timing for preventive maintenance action would be between the lower and upper bound values. However, the range in dynamic load for a given RQI value is wide. This makes it difficult to decide whether or not a particular pavement section that reaches the critical RQI range should be smoothed.

An accurate prediction of the critical roughness level that is likely to generate high dynamic truck loads requires the evaluation of dynamic axle loads generated by the profile characteristics of the individual pavement. One way to get dynamic axle loads is to use a truck simulation computer program. However this would require some knowledge of truck dynamics and a minimum fluency in truck parameters for specific components such as the suspension system, the chassis and the tires. It would be impractical for a state highway agency such as MDOT to adopt this approach. An alternative way would be to determine the relative increase in dynamic axle loads directly from the profile itself, since dynamic axle loading is a function of the pavement surface profile characteristics. This led to the development of a new profile index that predicts whether or not a profile is prone to generate high dynamic loads.

Development of Project-Level Roughness Threshold to Minimize Dynamic Loads

While RQI is a good general indicator of dynamic load, with plots of dynamic axle load against RQI having high R^2-values (ranging from 0.850 to 0.948), a wide range of dynamic loads can exist for a given RQI value. This is because RQI was developed based on passenger car response to pavement surface. This makes it difficult to decide whether or not a particular pavement section should be smoothed based on RQI because damage in pavements is caused mainly by heavy truck axle loads. To solve this problem, a new index (Dynamic Load Index), which better represents dynamic axle load was developed from the profile PSD curve.

Development of New Roughness Index (DLI)

DLI is calculated as a weighted index of variances of the profile elevation in the frequency ranges 1.5-4 Hz and 8-15 Hz. The first frequency range is where truck body bounce occurs, while the second frequency range corresponds to axle bounce. DLI is calculated according to the following steps:

- Transform the original profile into the wavenumber domain using the Fast Fourier Transform (FFT) algorithm.
- Split the transformed profile into two profiles that have wavelength ranges of 22 - 59 ft and 6 - 11 ft, respectively. This can be done by forcing zero amplitudes for all wavelengths except for the above critical wavelength ranges.
- Transform the above two profiles back to the space domain using the Inverse FFT (IFFT) algorithm.
- Calculate standard deviations (V_1 and V_2) from both profiles for each 0.1-mile section.
- Calculate DLI for each 0.1-mile section as $DLI = \sqrt{a_1 V_1 + a_2 V_2}$

The values for the weighting factors, a_1 and a_2, were determined as those which gives the highest correlation between the DLI and dynamic load.

The analysis showed very good relationships between DLI and dynamic load. The DLC-DLI relationships had R^2-values of 0.971, 0.969 and 0.960 for rigid, composite and flexible pavements, respectively, while those between 95th percentile dynamic load and DLI had R^2-values of 0.956, 0.929 and 0.929, respectively. These R^2-values are higher than those of the relationship between RQI and dynamic load. Therefore, it can be stated that the DLI is a good indicator of dynamic axle loads. It can differentiate between profiles that generate high dynamic loads and those having the same RQI but generating low dynamic loads. Most importantly, the use of the DLI index negates the need for running a truck simulation program. This makes it possible to decide whether a particular pavement section with a given surface profile needs smoothing based on the DLI-value. Thus the DLI can be used as a project-level roughness index for deciding whether or not to smooth a pavement based on dynamic load considerations.

Development of DLI Threshold Value and Corresponding Life Extension

DLI threshold values and corresponding life extensions were determined using relative damage and reduction in pavement life concepts. Using the 4th power law, relative damages from the 95th percentile dynamic load at different DLI values and the corresponding percent reduction in life were calculated and plotted for 333 sections. The percent reduction in pavement life was calculated using following equation.

$$R = \text{Percent Reduction in Pavement Life} = 100\% \, [1 - (\text{Relative Damage})^{-1}]$$

The life extension that can be achieved by smoothing a pavement section with a given remaining service life was determined as:

$$\text{Life extension} = (R - R_o)\, RSL$$

where R corresponds to the reduction in life at the current DLI value, and R_o corresponds to the reduction in life at the DLI value after the smoothing action.

The analysis was done for rigid, flexible and composite pavements with RSL values ranging from 20 to 6 years. Life extensions that can be expected for a range of RSL- and DLI- values were calculated and tabulated. Tables showing the predicted life extension achieved by smoothing a pavement section with a given remaining service life and different DLI levels were developed for the three pavement types. These tables can be used to decide on when smoothing action needs to be taken to get a desired life extension for a particular project.

Determining Optimal Timing for Smoothing Preventive Maintenance Action

The ability to predict DLI growth with time is necessary in order to accurately predict the optimum timing for the preventive maintenance action. The ability to predict future DLI-values given a current DLI would enable the PM division within MDOT to plan roughness-related PM actions a few years prior to the pavement reaching the DLI threshold-value. A reliability-based model for selecting the optimal timing (or planning period) for such preventive maintenance action was proposed using the new DLI-thresholds and actual DLI-growth rates from in-service pavements.

In order to implement a preventive maintenance strategy using the roughness threshold concept developed in this study, it is useful to define a "trigger" value equal to:

$$DLI_{trigger} = DLI_{threshold} - \Delta DLI$$

where $DLI_{trigger}$ represents the trigger-value for planning the smoothing PM action some years down the road.

The time (in years) corresponding to ΔDLI can be called the *PM Planning Period (PMP)*. On the other hand, the number of years left to reach the DLI threshold, given the current DLI-value is the *Remaining Smooth Period (RSP)*. The RSP is by definition greater than or equal to the PMP. At the trigger DLI-value, the RSP becomes the PMP.

In order to successfully plan for such PM-actions, it is necessary to have a reliable prediction of DLI growth with time. A useful way to interpret the DLI growth data is to use the actual growth rates from each individual pavement section and develop the probability distribution of the DLI growth rate. These results can then be used to calculate the reliability of the PM planning period, PMP, for different $DLI_{trigger}$-values. A similar analysis using existing RQI data was done in this study. In this analysis, the RQI growth rate for 1382 (805-m or 0.5-mile) sections from 112 rigid pavement projects were obtained from MDOT database. Probability distributions of RQI growth rate for 1, 2, 3 and 4 years were made. The same analysis can be done for the DLI. The results can be used to calculate the reliability that the pavement will not reach the threshold DLI-value before *x* years for different $DLI_{trigger}$-values, with *x* being the PM planning period.

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

Dynamic pavement loading due to the mix of commercial heavy trucks that make up the national fleet has been steadily increasing in the US as the national highway network continues to age. While this may be somewhat counteracted by an increase in the use of "road-friendly" vehicles, truck loading and its dynamic component remain a major cause of road damage. Previous research has suggested that dynamic wheel loads, caused by surface roughness, can be up to 40 percent higher than static loads (Gillespie et. al. 1993). All road surfaces have some level of roughness even when they are new, and they become increasingly rougher with age depending on pavement type, traffic volume, environment etc. This process is the result of the interaction between vehicles and pavements. Accordingly, it is reasonable to assume that there is a threshold value in roughness where dynamic load increases sharply leading to acceleration in pavement damage. If this threshold value exists, it could be a useful preventive maintenance (PM) tool, whereby a PM action, such as smoothing the pavement surface, is taken to extend the service life of a given pavement for several years.

Many government and state agencies use roughness as one of the objective measures for the management of their pavement network. The Michigan DOT uses its own Ride Quality Index (RQI) to characterize surface roughness. MDOT has also been surveying surface distresses for the entire pavement network in a systematic fashion, since 1992. The Distress Index (DI) is used to quantify the severity and extent of surface distresses along a project. In this paper, measured roughness and distress index data from pavement network in Michigan were analyzed for the purpose of determining RQI-threshold values. This analysis is aimed at minimizing pavement damage due to dynamic loading.

Once the RQI threshold is determined, it will be possible to extend the service life of the pavement by taking preventive maintenance action in the form of smoothening of the pavement surface (by way of milling, grinding or a thin overlay). In order to predict the optimum timing for the preventive maintenance action, the ability to predict RQI growth with time is necessary. This can be critical if a pavement that has reached the roughness threshold value is prone to start showing a sharp increase in distress accumulation. Ideally, it would be desired to have the ability to predict future RQI-values accurately given a current RQI. An alternative way is to calculate the probability that a certain pavement section reaches the RQI-threshold in a given number of years based on actual RQI increase rates of pavements in Michigan's pavement network. This would enable MDOT to plan roughness-related PM-actions before the pavement reaches the RQI threshold-value.

1.2 HYPOTHESIS AND OBJECTIVES

An increase in pavement roughness leads to higher dynamic axle loads in certain portions of the road. This amplification in the load magnitude can lead to a tangible acceleration in pavement distress and then, the increased distress makes pavement surface rougher. This interaction and relationship between pavement damage and load/or roughness provides give an early warning to the pavement management agency under the following hypothesis;

- As pavement becomes rougher, axle load fluctuation (bounce) increases causing more damage. There is a certain value of roughness (roughness threshold value) that causes a sharp increase in dynamic load and so, in pavement damage.
- There is a phase lag between the time when pavement reaches this roughness threshold value and the time when pavement needs to be rehabilitated.
- If this phase lag is on the order of a year or more, it is possible to propose a preventive maintenance action in the form of smoothing of the pavement surface (by way of milling, grinding or a thin overlay) which will extend the service life of the pavement by several years.

The objectives of this research are to:

- Test the above hypothesis
- Develop a threshold or a set of criteria, based on roughness and dynamic loading considerations
- Determine the optimal timing of the preventive maintenance action aimed at extending the pavement service life.

These objectives were achieved by using two parallel approaches: 1) a mechanistic approach, relating dynamic loading to pavement profile; and 2) an empirical approach, relating pavement distress to surface roughness at increasing levels of surface roughness.

1.2 MEASUREMENTS OF PAVEMENT SURFACE CONDITION

1.3.1 Pavement Surface Roughness

Roughness is not only an indicator of road surface condition but also excites the dynamic behavior of trucks, thus increasing damage. There are several ways for quantifying road roughness. One of the most widely used parameters is the International Roughness Index (IRI). Another way of quantifying road roughness is the Ride Quality Index (RQI), which was developed and is being used by MDOT

1.3.1.1 International Roughness Index (IRI)

The IRI was developed to provide a common quantitative basis on which the different measures of roughness can be compared. The IRI has been adopted as a standard for the FHWA Highway Performance Monitoring System (HPMS) database. The IRI is calculated from a measured longitudinal road profile by accumulating the output from a quarter-car model and dividing by the profile length to yield a summary roughness index with units of slope (Sayers, 1995). MDOT does not use the IRI for its PMS, but calculates it for its HPMS reporting system.

1.3.1.2 Ride Quality Index (RQI)

As its name suggests, the RQI describes the ride quality of the road. In the early 1970's MDOT conducted a study to determine an objective measure that would correlate ride quality to the subjective opinions of highway users. Using "Psychometric" tests, it was found that some components of a road have a strong effect on user opinion, while others have a significantly lesser effect (Michigan DOT, 1996). Through a series of mathematical and statistical steps, the Power Spectral Density (PSD) was found to correlate at 90 percent with subjective opinions. Based on this, the profile is split into three wavelength bands: 0.6-1.5 m (2-5 ft), 1.5-7.6m (5-25ft), and 7.6-15.2 m (25-50ft). Wavelengths shorter than 0.61 m (2 ft) mostly create tire noise and those longer than 15.2m (50 ft) fail to disturb the vehicle suspension. The RQI is calculated from these three PSD wavelength bands according to the equation shown below (Darlington, 1995):

$$RQI = 3 \ln (Var1) + 6 \ln (Var2) + 9 \ln (Var3)$$

where: Var1, Var2 and Var3 are variances for 7.6-15.2 m, 1.5-7.6m and 0.6-1.5 m wavelengths, respectively.

An RQI value between zero and 30 indicates excellent ride quality, 31 to 54 good ride quality, 55 to 70 fair ride quality and more than 70 is considered poor pavement ride quality (Darlington, 1995). The longitudinal profile for the entire pavement network in Michigan is measured annually using a Rapid Travel Profilometer (RTP). The data are used to calculate both the RQI and the IRI (International Roughness Index), which is reported to the Federal Highway Administration (FHWA).

1.3.2 Pavement Damage Evaluation

The MDOT collects both functional and structural distress data to assess the surface condition of the pavement for the entire pavement network (no sampling). Distress data are collected by videotaping 50 percent of the pavement network every year. The videotapes are reviewed manually and each distress on the pavement surface within each 10-ft long section is identified, reviewed, checked, scored and stored in the PMS databank. Hence the data includes information on the status of each crack and its location within the 10-ft long section. The distress data are then grouped into surveying unit sections that are 0.1-mile long. Thus the PMS databank contains, for each 0.1-mile segment of the road, detailed data for each type of pavement distress and the severity and extent of the 'associated distress'. The term 'associated distress' is used in MDOT rehabilitation practice to denote secondary distresses associated with the principal distress. For example, 'spalling' associated with a transverse crack would be considered as 'associated distress' for the transverse crack.

The MDOT PMS group has developed a rating system whereby each type of principal distress and its associated distress level are ranked and assigned 'Distress Points' (DP) based on their impact on pavement performance and on experience. For any pavement section, the Distress Index (DI) can be calculated as the sum of distress points along the section normalized to the section length. The length of the pavement section (L) is expressed in terms of 161 m (0.1mile) unit-sections. The equation for the DI follows:

$$DI = \Sigma DP/L$$

where: DI = Distress Index
Σ DP = Sum of the distress points along the pavement section
L = Length of the pavement section in 161m (0.1 mile) unit sections

The DI scale starts at zero for a perfect pavement and it increases (without a limit) as the pavement condition worsens. MDOT categorizes DI into three levels: Low; <20, Medium; 20-40, and High; >40. A pavement with a DI of 50 is considered to have exhausted its service life; hence its remaining service life (RSL) is zero, and it is a candidate project for rehabilitation. This DI-threshold-value was established based on historical pavement performance.

1.4 SCOPE OF THE REPORT

The report includes seven chapters and several appendices. The current chapter (Chapter 1) gives some background information on the research undertaken and states the working hypothesis and the objectives of the research study.

Chapter 2 gives a brief literature review on relevant subjects including pavement surface roughness, its measurement and profile attributes, dynamic vehicle modeling, and truck-pavement interaction.

In Chapter 3, because the relationship between dynamic truck loading and pavement distress is complex and not well understood to this date, an attempt is made to show how one could use roughness and distress data together for the purpose of discerning between cases of dynamic-load-related distress accumulation and other non-load-related distress accumulation. For this analysis, ten sites from the Michigan pavement network with known performance records and having exhibited some distress in the time period between 1992 and 1997 were used.

Chapters 4 and 5 deal with testing the hypothesis adopted in this research, i.e., the existence of roughness thresholds at which there is a notable increase in dynamic truck loading that will accelerate pavement damage and distress accumulation. Two parallel approaches were used:

1) An empirical approach (Chapter 4), relating pavement distress to surface roughness at increasing levels of surface roughness;
2) A mechanistic approach (Chapter 5), relating dynamic loading to pavement profiles.

In Chapter 4, the relationship between the distress index (DI) and the roughness index (RQI) was sought using measured distress and roughness (RQI) data for 97 projects totaling 1,437 0.5-mile sections that have different ages and levels of distress and roughness.

In chapter 5, the relationship between dynamic axle load and road roughness was developed to confirm the existence of critical RQI-values mechanistically. For this analysis, actual surface profiles of 333 in-service pavement sections (0.1-mile long) from thirty-seven projects in Michigan were used to generate dynamic axle loads using the TruckSim™ truck simulation program. Relationships between RQI and the Dynamic Load Coefficient (DLC) as well as the 95th percentile dynamic load were developed for the three pavement types.

In chapter 6, a new roughness index (Dynamic Load Index), which represents a good indicator of the potential for high dynamic truck axle loads, was developed. This was deemed necessary because, even though the RQI is a good general indicator of dynamic loads, the range in dynamic truck axle loads for a given RQI value is wide. This is due to the fact that RQI was developed based on passenger car response to pavement surface roughness. This makes it difficult to decide whether or not a particular pavement section should be smoothed for the purpose of reducing dynamic truck loads, based on RQI, since pavement damage is caused primarily by heavy truck axle loads. The new DLI index negates the need for running a truck simulation program to determine whether a pavement profile is friendly/unfriendly from a dynamic loading aspect.

In chapter 7, using the new roughness index, DLI, roughness threshold values and the corresponding life extension predictions were determined based on relative damage and reduction in pavement life concepts. The analysis was done for rigid, flexible and composite pavements with Remaining Service Life (RSL) values ranging from 6 to 20 years. Based on this analysis, tables of expected life extension for a range of RSL- and DLI- values were provided. These tables would enable MDOT to determine when a particular pavement needs to be smoothed to obtain a given (desired) life extension.

Chapter 8 provides a summary of findings and outlines the main conclusions from the research. Finally, some practical implications for pavement management and preventive maintenance are put forward, and recommendations for future research are suggested.

CHAPTER 2
LITERATURE REVIEW

2.1 ROAD SURFACE ROUGHNESS

Hudson (1981) defined road surface roughness as a phenomenon that results from the interaction of the road surface profile and any vehicle that travels over that surface. It is experienced by the vehicle, its operator, and any passengers or cargo. Roughness is a function of the road surface profile and certain parameters of the vehicle, including tires, suspension system, body mounts as well as of the sensibilities of the passengers and driver to vertical acceleration and speed.

A road surface profile contains roughness waves or undulations of a length that, when driven over at a particular speed, produce an excitation in the vehicle at one of the vehicle's resonant frequencies. A normal vehicle is a simple mechanical vibrating system made up of the mass of the vehicle, the springs on which it rides, and the shock absorbers. At a particular frequency of vibration of bouncing of any vehicle, the vibration tends to increase in amplitude. This is called the resonant frequency of the vehicle. At any particular speed of travel, there is a road profile wavelength that will excite the vehicle at one of its resonant frequencies and thus cause excessive vibration or bouncing. If the amplitude of that resonant wavelength is large, the vibration or vertical accelerations imparted to the vehicle may be quite noticeable. Since vertical accelerations impart significant vertical force, these wavelengths result in significant forces applied to the road, which can result in damage to road (Hudson, 1981).

In general, most vehicles in a particular class possess similar characteristics and, for any particular road surface, most vehicles in the same class will be driven at about the same speed. The excitation of the vehicle becomes primarily a function of the wavelength content of the road profile surface (Hudson, 1981).

2.1.1 Types of Roughness-Measuring Equipment

Road roughness is measured by two types of equipment: Response-type equipment that measures the vehicle response to roughness; and profilometers that measure actual profiles.

The response-type measurement system records the dynamic response of vehicle mechanical systems as they travel over the rough road at some constant speed. It is, therefore, a relative measurement and depends on the characteristics of vehicle mechanical system and the speed of travel. Different road roughness measurement systems use vehicles with similar, but not identical, response characteristics. Thus the axle-body motions generated by different systems are weighted somewhat differently and derived from different portions of the road roughness frequency spectrum (Gillespie et al., 1980).

This type of equipment includes the Bureau of Public Roads (BPR) roughometer, the Portland Cement Association (PCA) meter and the Mays meter. BPR roughometer is a single wheel trailer that measures the vertical movements of the damped, leaf-sprung wheel with respect to the frame by a mechanical integrator. The results are recorded on counters to produce an inches-per-mile count of roughness. This method of measurement is the simplest and least expensive. However, the measurements are intimately tied to vehicle response, which varies among vehicles and also varies with time, vehicle conditions and weather, Thus these measurements are less accurate in general, and require a fairly complicated calibration to convert the measurements to a standard scale (Wambold et al., 1981). This type of equipment is used by many state highway and transportation agencies because of the advantages of relatively low cost, simplicity of operation, and high measuring speed.

Another type of measurement system is the profilometer. It measures the longitudinal elevation profile of the road. The advantage of a profilometer is that it contains complete information about the pavement profiles that can be evaluated according to specific needs. This type of equipment include(Wambold et al., 1981):

- General Motors Research (GMR) profilometer
- French Bridge and Pavement Laboratory (LCPC) longitudinal profile analyzer (APL)
- Transport and Road Research Laboratory (TRRL) Beam
- CHLOE (AASHO) profilometer

The GMR profilometer is a device that has been developed to measure the profile of one or two road tracks at speeds comparable to the speed of highway traffic. An accelerometer measures the vertical motion of the body of the vehicle. The profile is obtained by doubly integrating the accelerometer signal and then subtracting the displacement signal to eliminate vehicle motion from the measurement (Gillespie et al., 1980). The CHLOE profilometer measures the difference in angles between a small beam with two wheels, 9 in. apart, and the much longer CHLOE trailer, measuring 25.5 ft in length. In order to eliminate any dynamic phenomena, the CHLOE must be towed at a low speed, typically 2 to 3 mph (Gillespie et al., 1980).

2.1.2 Road Profile Filtering

Gillespie and Sayers (1981) suggested filtering a road profile because the true variation in profile elevation is not suitable as a measure of roughness. The inclusion of hills would yield roughness measures that are dominated by the height of the hills. If the road is going up a hill, even if the road is perfectly smooth, the elevation will change considerably, and a high variation would be obtained because of the hill, not the road surface. This large amplitude deviation has no effect on vehicle response. Therefore the underlying hill needs to be removed. Also, according to Kenis (1995), experimental measurements of tire enveloping properties have shown that truck tires filter short wavelengths from the road by enveloping small bumps. The above long and short wavelengths filtering can be done by a moving average filter. A profile can be smoothed by averaging adjacent elevation values together. The filtered profile can be obtained by the following equation (Kenis, 1995);

$$X_H = \frac{1}{2\lambda_c} \int_{x-\lambda_c}^{x+\lambda_c} X_R(x)dx$$

$$X_L = X_R - X_H$$

where X_R = raw profile, X_L = low-pass profile, X_H = high-pass profile, λc = the cutoff wavelength of the moving average filter.

2.1.3 Evaluation of Road Profile

Road roughness is the major cause of dynamic load variations on heavy trucks, and roughness inputs are therefore needed for the vehicle models. When a vehicle is traveling in a straight line, the input to each wheel is described by a longitudinal profile of the pavement. Because the vehicle sees the road as a continuously varying vertical input, the road elevations under the wheels appear as variables that change randomly with time. Road profiles fit the general category of broad-band random signals and can be described either by the profile itself or its statistical properties. One of the most useful representations is the Power Spectral Density (PSD) function (Gillespie, 1993; and Cebon, 1999).

2.1.3.1 Power Spectral Density Function

Like any random signal, the road profile can be decomposed by the Fourier Transform process into a series of sine waves varying in their amplitudes and phase relationships. A plot of the amplitudes versus spatial frequency is the PSD. Spatial frequency is expressed as the wavenumber with units of cycles/foot, and is the inverse of the wavelength of the sine wave on which it is based.

If a road profile is denoted by $y(x)$ and the profile is a realization of a stationary Gaussian random process then the profile can be fully described by the spatial autocorrelation function:

$$\phi_{yy}(\delta) = E[y(x)y(x+\delta)]$$

The autocorrelation function is also related to the Power Spectral Density by the Fourier transform:

$$S_{yy}(n) = \int_{-\infty}^{\infty} \phi_{yy}(\delta) \exp(-i2\pi\delta n) d\delta$$

where n is the wavenumber.

The PSD of any particular road section is unique. However, when a number of PSDs of different sections are compared, a general similarity in their shape is evident. This leads to the model of an average road, defined by a PSD.

2.1.3.2 *Artificial Road Profile Generation*

Various types of road models have been in use for years as a means to represent roads for analyzing vehicle ride behavior (Gillespie and Sayers, 1981). One of the first proposed stochastic models is an equation of the form:

$$G_z(\nu) = A/(2\pi\nu)^2$$

where $G_z(\nu)$ is the PSD function of elevation (z), ν is a wavenumber, and A is a roughness coefficient obtained by fitting the PSD of a measured road to the above equation.

As the elevation is perceived to be changing with time, it also has a velocity (proportional to slope) and acceleration (proportional to the derivative of slope), which also have PSDs for the same road section. Since velocity is the derivative of position, the velocity PSD is related to the elevation PSD by the scale factor ($2\pi\nu$). And, likewise, the acceleration PSD is related to the velocity PSD by the same scale factor. The concept of the road as an acceleration input to the vehicle is important to understand because its ultimate effect -vehicle ride vibration- is invariably quantified as accelerations (Gillespie and Sayers, 1981). Gillespie et al. (1993) proposed the following equation for the PSD model:

$$G_z(\nu) = G_a/(2\pi\nu)^4 + G_s/(2\pi\nu)^2 + G_e$$

The first component, with the amplitude G_a, is a white noise acceleration that is integrated twice. The second, with amplitude G_s, is a white noise slope that is integrated once. The third, with amplitude G_e, is a white noise elevation. The model can also be written to define the PSD of profile slope by looking at the derivative of the above equation.

$$G_z'(\nu) = G_a/(2\pi\nu)^2 + G_s + G_e(2\pi\nu)^2$$

Gillespie et al. (1993) suggested ranges of roughness parameters based on the road profiles measured in North America, England and Brazil (Table2.1).

TABLE 2.1 Roughness Parameters for the White-Noise PSD Model (Gillespie et al., 1993)

Surface type	G_s (m/cycle× 10^{-6})	G_a (1/m cycle ×10^{-6})	G_e (m^3/cycle ×10^{-6})
Asphalt(Ann Arbor)	1~300	0.0~7	0.0~8.0
Asphalt(Brazil)	4~100	0.4~4	0.0~0.5
PCC(Ann Arbor)	4~ 90	0.0~1	0.0~0.4
Surface treatment (Brazil)	8~ 50	0.0~4	0.2~1.2

When traversed by a vehicle, the profile is perceived as an elevation that changes with time, where time and longitudinal distance are related by the speed of the vehicle. The time-varying elevation can also be characterized by a PSD that has units of elevation.

Marcondes et al. (1991) developed another equation to predict PSD. Elevation profiles of federal and interstate highways near Lansing, Michigan, were measured with a profilometer and PSD were calculated. They developed the following equations to fit the above data:

$$PD_{pe}(\nu) = A_1 \exp(-k\nu^p), \qquad \nu \leq \nu_1$$
$$PD_{pe}(\nu) = A_2 (\nu-\nu^o)^q, \qquad \nu > \nu_1$$

where $PD_{pe}(\nu)$ = power density value [in^3/cycle] for the pavement elevation
ν_1 = discontinuity frequency, cycles/in
ν_o = asymptote frequency, cycles/in
A_1, A_2, k, p, q = constant

Marcondes (1993) reported the range of values of parameters for the equations as shown in Table 2.2.

TABLE 2.2 Ranges of Variable Values for PSD Equations (Marcondes, 1993)

Category	A_1	k	p	A_2	v_o	q
OC	1.3~7.2	7000~ 67000	1.6~2.0	5.9E-7~ 4.2E-5	0~ 3.9E-3	-2.6~ -1.5
NC	1.5~3.4	24000~ 83000	1.8~2.0	6.0E-7~ 6.0E-5	2.5E-3~ 4.9E-3	-2.2~ -1.1
AC	1.8~5.7	63000~ 240000	2.0~2.2	1.4E-4 7.7E-4	4.6E-3~ 5.2E-3	-1.1~ -0.5

Note: OC: old concrete pavement; NC: new concrete pavement; and AC: asphalt concrete pavement.

They investigated the relationship between RMS (Root Mean Square) elevation and IRI (International Roughness Index); the measured data showed that the correlation between them is weak (R^2 <0.7). It was found that a good correlation exists between the IRI and the PSD only for spatial frequencies between 0.002 and 0.015 cycle/in.

From the same data, Marcondes et al. (1992) found strong correlations between the IRI and the RMS vertical acceleration at the truck bed. The following models were developed for these relationships:

- For vehicle speed = 45 mph:

$$RMS = 3.794E\text{-}2 + 1.902E\text{-}3 \cdot IRI - 8.89E\text{-}7 \cdot IRI^2 \qquad (R^2=0.937)$$

- For vehicle speed = 52mph:

$$RMS = 4.467E\text{-}2 + 2.144E\text{-}3 \cdot IRI - 1.819E\text{-}6 \cdot IRI^2 \qquad (R^2=0.914)$$

- For vehicle speed = 60 mph:

$$RMS = 0.105 + 1.25E\text{-}3 \cdot IRI - 1.63E\text{-}6 \cdot IRI^2 \qquad (R^2=0.866)$$

Most researchers have used generated road profiles for dynamic vehicle simulation. Road profiles, like any other random signal, can be generated using a random number algorithm. To generate random numbers, Gillespie et al. (1993) used a Gaussian distribution with a mean value of zero, and the standard deviation is:

$$s = (G/2\Delta)^{1/2}$$

where G is a white-noise amplitude for one of the three coefficients; G_s, G_e and G_a.
Δ is the interval between samples, expressed in the inverse units used for wavenumber.

A simulated road profile that matches the target PSD is generated using the following procedures:

1) Create an independent sequence of random numbers for each of the three white-noise sources, scaled according to the above equation.
2) Integrate each sequence as needed to obtain the desired distribution over wavenumber..
3) Sum the outputs of the filters.

Thus, the sequence corresponding to the G_a term is integrated twice, the sequence corresponding to the G_s term is integrated once, while the sequence corresponding to the G_e term is not integrated. Table 2.3 shows PSD coefficients and IRI values used by Gillespie et al. (1993).

TABLE 2.3 PSD Coefficients in the Roughness Model (Gillespie et. al., 1993)

Pavement Type	Surface Type	IRI (in/mi)	G_s (m/cycle×10^{-6})	G_a 1/(m×cycle×10^{-6})	G_e (m^3/cycle×10^{-6})
Flexible	Smooth	75	6	0.00	0.000
	Medium	150	12	0.17	0.000
	Rough	225	20	0.20	0.003
Rigid	Smooth	80	1	0.00	0.000
	Medium	161	20	0.25	0.100
	Rough	241	35	0.30	0.100

In the case of a rigid pavement, faulting and curling/warping should be considered. The slab roughness between joints has similar characteristics to that of a flexible pavement; and, therefore, the periodic faults caused by the slab joints are superimposed on to this model. The resulting road profile over a slab length is:

$$y(x) = y_r(x) + y_{jf}(x)$$

where $y_r(x)$ is the profile due to the slab roughness, and

$$y_{jf}(x) = \begin{cases} (h/L)x & \text{for } 0<x<L, \\ 0 & \text{for } x=L \end{cases}$$

where h = joint fault magnitude
L = joint spacing

Thermal and moisture gradient across the slab thickness result in significant bending moments along the edges of the slab. The curling/warping is modeled as a periodic hemispheric wave added to the above road model:

$$(x\text{-}L/2)^2 + (y_w(x)\text{-}(L/2\text{-}\delta))^2 = R^2 \; ; \quad R^2 = (L/2)^2 + (R\text{-}\delta)$$

where δ = mid-slab deflection due to warping
R = radius of curvature of slab
L = slab joint spacing
y_w = vertical displacement due to warping

The final road profile is :

$$y(x) = y_r(x) + y_{jf}(x) + y_w(x)$$

2.1.4 Roughness Prediction Models

Pavement surface roughness is one of the measurements of pavement performance. Several researchers developed roughness prediction models considering several factors that are thought to cause roughness.

Moody (1997) developed an IRI prediction model for jointed plain concrete pavements using Long-Term Pavement Performance (LTPP) data of the Strategic Highway Research Program (SHRP). He used several factors, such as age, concrete modulus, average annual wet days, and traffic. The following are the linear prediction models developed:

$$IRI = 55.5 + 4.76 \times Age + 4.0E-06 \times MOE + 2.7E-0.3 \times AVWET^2 \qquad (R^2=0.41, n=65)$$

$$IRI = -20.2 + 5.408 \times KESALs + 3.6E-06 \times MOE + 2.6E-0.3 \times AVWET^2 \qquad (R^2=0.21, n=62)$$

where: IRI = international roughness index (cm/km)
Age = pavement age (years)
MOE = concrete modulus of elasticity (kPa)
AVWET = average annual wet days

According to Moody, this model should include the initial pavement roughness, which is thought to have a significant effect on pavement long-term performance. However, it was not included in this model because it is not available from LTPP data.

Rowshan (1988) developed a roughness prediction model for flexible pavements with granular base and bound base using LTPP data. He grouped flexible pavements with granular base into six categories according to climatic factors and subgrade property. For each group of pavements, a prediction model was developed using several factors out of a pool of factors that total twenty-one. R^2-values of those models ranged from 0.299 to 0.724. Flexible pavements with bound base are grouped into five categories according to base types. R^2-values of the regression models for these pavements ranged from 0.59 to 0.97. From the results of this analysis, Rowshan concluded that age is the most dominant factor and climatic elements are the second important factor, followed by material characteristics and structural factors.

The effect of initial pavement smoothness on future pavement smoothness was studied by Smith (1997) using 208 new projects and 169 overlaid projects from 10 states. He developed roughness models for each project by doing regression analysis using the available time-series roughness data. He used this models to predict the service lives, which correspond to the time at which the pavement reaches the critical roughness level of 175 in/mile. For the regression analysis, the following form was used:

$$S_t = a_o + a_1 S_i^{b1} + a_2 t^{b2} + a_3 S_i^{b3} t^{b4}$$

where, S_t = pavement smoothness at time t

a_o, a_1, a_2, a_3,b_1, b_2, b_3, b_4 = regression coefficients

S_i = initial pavement smoothness

t = time in years

From the results of the regression analysis, Smith calculated p-values of the initial smoothness regression coefficient a_1. For this evaluation, the significance level of 10 % was selected. Results of significance analysis indicated that 80% of new projects and 70% of overlaid projects show a significant effect of initial smoothness on future smoothness.

2.2 DYNAMIC VEHICLE MODELING

Models to simulate the behavior of moving vehicles have been developed for several commercial trucks. These include:

- General purpose analysis programs such as NASTRAN, ADAMS, DADS and others (Gillespie et al, 1993)
- Programs that are specifically written for vehicle dynamics applications such as the FHWA program T3DRS developed by UMTRI (Gillespie et al, 1993)
- UMTRI PHASE-4 program which was later improved and renamed as TRUCKSIM (Gillespie et al, 1993)
- Cambridge program (Cebon, 1985), the VESYM model (Hedrick, 1988)
- VSIM2D (Kenis et al, 1995)

These models represent analytically the dynamic behavior of the component rigid bodies, axle suspensions, and tires as the vehicle moves along a pavement of specified roughness at a specific speed. The models are planar (2-dimensional), with pitch being the only form of rotation allowed. (Pitch is the rotation seen by an observer from the side of the vehicle). The vehicle in these models is treated as several rigid bodies represented by lumped masses and connected by compliant linkages (springs and dashpots). The vehicle body is the primary mass, and is supported by suspension systems at each axle. It is denoted as the "sprung mass". Additional masses considered are those concentrated at each axle, and they take into account the masses of the axle, brakes, wheels etc. These are denoted as "unsprung masses" (Gillespie et al, 1993). Figure 2.1 shows an example model of a tractor-semitrailer. Some basic truck parameters used in truck simulation models are summarized below.

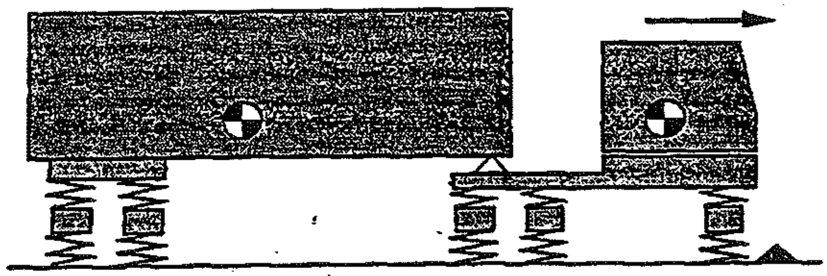


FIGURE 2.1 Rigid Body Model of a Tractor-semitrailer (Gillespie et al., 1993)

2.2.1 Vehicle Parameters

Gillespie et al. (1993) simulated 15 different types of truck configurations that have 2 to 9 axles using the UMTRI Pitch-Plane Model. Suspension and tire parameters used in this simulation are listed in Tables 2.4 and 2.5. Hedrick et al. (1988) simulated a 5-axle semi-trailer using the VESYM Program. Vehicle parameters used in this simulation are listed in Tables 2.6 and 2.7. Kenis et al. (1995) simulated a 2-axle truck using VSIM2D Computer Program. Truck parameters are listed in Tables 2.8 and 2.9. Vehicle parameters used for simulations by Cebon (1985) are listed in Tables 2.10 and 2.11.

2.2.2 Suspension Systems

Suspensions are a key system that needs to be modeled properly in order to accurately predict the dynamic load response to surface roughness. The most popular suspension system on heavy trucks in the U.S. is the leaf-spring type. A side view of the basic layout of a 4-spring suspension is shown in Figure 2.2. Existing models can predict the behavior of leaf-spring suspensions very well up to a frequency of 15 Hz. The errors above the 15 Hz range are of no consequence because vibrations on the axle at higher frequencies do not propagate down to the tire contact patch (Gillespie, 1993).

The second most popular suspension is the air-spring system. Figure 2.3 illustrates a side view of such suspension. Air springs are unique in the sense that the load is supported by air pressure, which is automatically adjusted to accommodate changes in the load (Gillespie et al, 1993). The air-spring suspension is best if the system is properly and continuously maintained. However, if proper maintenance is not provided this type of suspension would lead to very rough rides.

The third major suspension system is the walking beam type (only applicable to tandem axles). This type of suspension is used only on a small fraction of trucks nowadays. It is most commonly found in vehicles that need to run on off roads (dirt and gravel haulers, timber haulers, etc.) A side view of this type of suspension is shown in Figure 2.4 (Gillespie et al, 1993). The walking beam suspension is known to be rugged, but it has been shown to cause the most significant levels of dynamic loading.

TABLE 2.4. Suspension Parameters (Gillespie et al., 1993)

Suspension Location	Suspension Type	Upper Envelope Stiffness(lb/in)	Lower Envelope Stiffness(lb/in)	β	Damping Coefficient (lb.sec/in)	Unsprung Weight (lb)
Steer Axle	Flat Leaf(12k)	1650	1350	0.080	16	1400
Steer Axle	Taper Leaf	1075	925	0.160	16	1400
Steer Axle	Flat Leaf(18k)	2400	2100	0.080	16	1400
Single Drive Axle	Leaf Spring	3300	2700	0.080	36	2400
Tandem Drive Axle	4-Spring Flat	3300	2700	0.080	36	4700
Tandem Drive Axle	4-Spring Taper	2200	1800	0.160	36	4700
Tandem Drive Axle	Air Spring	100	900	0.150	50	4700
Tandem Drive Axle	Walking Beam	18000	15000	0.050	0	4900
Drop Axle	Air Spring	1000	900	0.150	50	1400
Single Semitrailer	Leaf Spring	3300	2700	0.080	36	1500
Tandem Semitrailer	4-Spring Flat	3300	2700	0.080	36	3000
Tandem Semitrailer	4-Spring Taper	2200	1800	0.160	36	3000
Tandem Semitrailer	Air Spring	1000	900	0.150	50	3000
Single Trailer	Leaf Spring	3300	2700	0.080	16	1500
Tandem Trailer	4-Spring Taper	2200	1800	0.080	36	3000

TABLE 2.5 Tire Parameters (Gillespie et al., 1993)

Tire Type	Stiffness (lb/in)	Damping Rate (lb-s/in)
Conventional Single	4700	6.0
Wide Based Single	7000	6.0
Conventional Dual	4700	6.0
Heavy Duty Dual	6000	6.0

TABLE 2.6 Suspension Parameters (Hedrick et al., 1988)

Suspension Location	Suspension Type	Upper Envelope Stiffness(lb/in)	Lower Envelope Stiffness(lb/in)	β	Damping Coefficient (lbf s/ft)	Unsprung Weight (slugs)
Steer Axle	Leaf Spring	1291	861	0.002	1.0	40
Drive Axle	Leaf Spring	6250	4167	0.002	1.0	53
Trailer Axle	Leaf Spring	6250	4167	0.002	1.0	45

TABLE 2.7 Tire Parameters (Hedrick et al., 1988)

Tire Type	Stiffness (lb/in)	Damping Rate (lbf-s/ft)
Single	5120	10.4
Dual	7000	20.8

TABLE 2.8 Suspension Parameters (Kenis et al., 1995)

Suspension Location	Suspension Type	Suspension Stiffness (lb/in)	β	Coulomb Friction (lb)	Unsprung Weight (lb)
Front Axle	Leaf Spring	1280	0.004	250	1475
Rear Axle	Leaf Spring	2925	0.001	500	1975

TABLE 2.9 Tire Parameters (Kenis et al., 1995)

Tire Type	Stiffness (lb/in)	Damping Rate (lbf-s/ft)
Single/Dual	5037	50

TABLE 2.10 Suspension Parameters (Cebon, 1985)

Suspension Location	Suspension Type	Upper Envelope Stiffness (kN/m)	Lower Envelope Stiffness (kN/m)	β (mm)	Unsprung Weight (kg)
Steer Axle	Multileaf	210	190	2.5	833
Tandem Drive Axle	Multileaf	1700	1600	0.5	1190

TABLE 2.11 Tire Parameters (Cebon, 1985)

Tire Type	Stiffness (kN/m)	Damping Rate (kNs/m)
Single	700/600(laden/unladen)	3.0

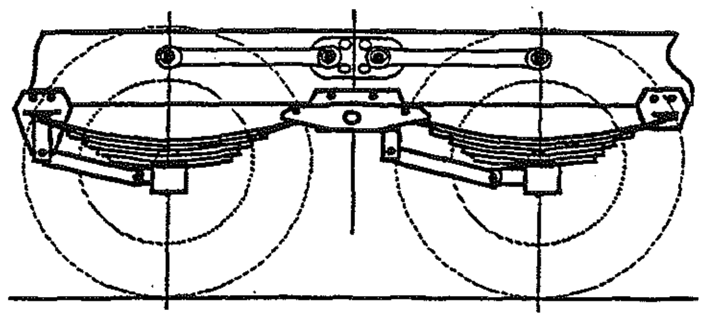


FIGURE 2.2 Side View of a 4-Spring Suspension (Gillespie et al., 1993)

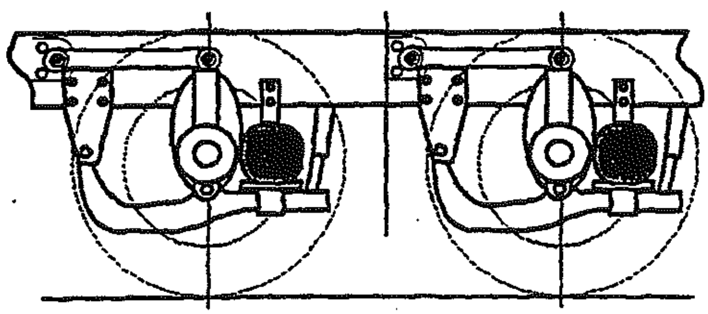


FIGURE 2.3 Side View of an Air Suspension (Gillespie et al., 1993)

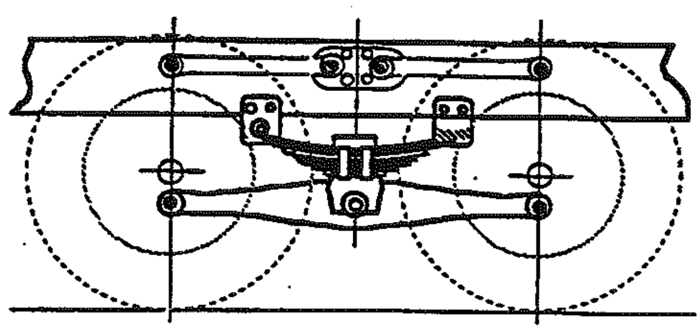


FIGURE 2.4 Side View of a Walking-Beam Suspension (Gillespie et al., 1993)

The suspension model used in this study is the leaf-spring suspension. A detailed description of the leaf-spring suspension model is given below.

Leaf-Spring Suspension Model

The leaf-spring element is a highly non-linear compliance element, due to the nature of the inter-leaf coulomb friction. The equation developed by Fancher (1980) was used to describe the hysteresis curve of the leaf-spring (Hedrick et al., 1988, Cebon, 1985, Abbo, 1987):

$$\partial F/\partial \delta = (F_{env} - F)/\beta$$

where F = leaf-spring force
δ = spring deflection
β = decay constant
F_{env} = force on the enveloped at the given deflection

A digital solution to this is given as :

$$F_i = F_{env\,i} + (F_i\text{-}1 - F_{env\,i\text{-}1})\exp(-|\delta_i - \delta_{i-1}|/\beta)$$

with '*i*' indicating the current time-step and '*i*-1' indicating the previous time-step; and

$$F_{env\,1} = k_1\delta + P$$
$$F_{env\,2} = k_2\delta + Q$$

where: subscript '1' indicates upper envelope and '2' the lower enveloped,
k_1, k_2 are the stiffness of the spring in loading and unloading,
P, Q are the intercepts of the enveloped at δ=0 for the upper and lower envelopes respectively.

2.2.3 Tire Models

Abbo (1987) reviewed the literature about tire models that had been used in dynamic vehicle simulations.

- Point contact tire model: The tire is assumed to be in contact with the terrain at a single point. The carcass and inflation pressure are modeled as a single spring in parallel with a damper that models the carcass energy dissipation due to stretching. This model does not model sharp irregularities in the terrain realistically.
- Rigid tread band tire model: The tire can contact the terrain in more than one point by modeling the tire geometry as a rigid tire. The spring /damper combination then experience a filtered version of the terrain that removes sharp irregularities.
- Fixed footprint tire model: Interaction with the terrain for this model is at a fixed contact length independent of the tire deflection. A set of spring/damper pairs are

evenly distributed along the contact length to model the carcass and inflation pressure.

- Adoptive Footprint Tire Model: It consists of a flexible tread band linked to the wheel center by angularly distributed stiffness and damping which simulate carcass and tread stiffness. The difference with the fixed footprint model is that the footprint length and orientation relative to the wheel center changes depending on tire deflection and terrain profile.

Abbo (1987) introduced the following procedure for getting vertical tire forces using the fixed footprint tire model:

- Obtain experimentally the vertical rolling force vs. tire deflection characteristic of the tire and determine the non-linear stiffness of the tire;
- Using the simulation model impose a series of center spring deflection in the loading range of the tire assuming a flat road surface. For each center spring deflection determine the sum of the vertical deflections of all the spring in the model.
- For each value of center spring deflection the sum of the deflection of all the spring can be obtained and the corresponding vertical tire force based on the experimental deflection vs. tire force data.

2.3 INTERACTION BETWEEN DYNAMIC AXLE LOAD AND PAVEMENT

Markow et al. (1988) developed a vehicle model and simulated the behavior of moving vehicles for several commercial trucks. The results of this simulation (tire force vs. time or distance) were used as inputs to the pavement response models, VESYS and PMARP, to predict pavement primary response of flexible and rigid pavements, respectively. By doing parametric studies, the interaction between dynamic vehicle load and pavement were analyzed. The results of this study showed the effects of the following rigid pavement characteristics on axle loads:

- Slab length: 20ft joint spacing produces a 12 percent increase in aggregate loading.
- Height of Joint Fault: There is up to a 20 percent increase for a change in fault height from 0.25 in to 0.75 in.
- Slab Warping: 1in deflection at the center of a 30 ft slab causes increase in aggregate loading up to 25 percent.
- Slab roughness: Interior roughness of the slab has relatively insignificant effect on vehicle load, compared to slab end effects.

The effect of vehicle parameters (single leaf-spring suspension) on pavements are:

- Leaf-Spring Stiffness: When the leaf-spring stiffness is halved, cracking damage is reduced by 10 percent.
- β parameter: A large value of β, or reduction in leaf-spring damping, produces a 12 percent reduction in cracking over the entire slab.

- Tire Pressure: 5.5 percent increase in load magnitude is obtained when raising the tire pressure from 75 to 125 psi.

Cole et al. (1995) and Cebon (1999) studied the effect of suspension parameters on truck dynamic loading. DLC-values for a wide range of suspension stiffness and damping were calculated using a quarter car model. Figure 2.5 shows contours of DLC for each stiffness and damping. The figure shows that the minimum DLC is 0.051 for a stiffness coefficient of 200kN/m and a damping coefficient of 25kNs/m.

Under an NCHRP Project, Gillespie et al. (1991) studied the mechanics of truck-pavement interaction. In this study, truck characteristics affecting pavement damage were evaluated for three levels of road roughness. Twenty-nine trucks were simulated using the UMTRI Pitch-Plane model. For pavement analysis, ILLI-SLAB was used for rigid pavement and VESYS-DYN for flexible pavements. Findings are as follows (T.D. Gillespie et al., 1991):

- Axle load: Fatigue damage is dominated by the most heavily loaded axles because of the power-law relationship of load and fatigue. Typical truck axle loads vary from 10-22 kips, and a 22 kip axle is 23 times as damaging as a 10 kip axle.
- Tandem axle: tandem axles are no more damaging than single axles with equivalent load per axle.
- Suspension types: The walking-beam suspension produces high dynamic loads. On rough and moderately rough roads, walking-beam suspensions can be more damaging than other suspension types by as much as 50%.
- Axle spacing : axle spacing is not an important truck characteristic affecting pavement damage.
- Tire inflation pressure: Elevated tire inflation pressure greatly increases the fatigue damage of flexible pavements. Overinflation by 25 psi nearly doubles flexible pavement fatigue. However tire pressure has a moderate influence on rigid pavement fatigue .
- Roughness: A rough pavement (PSI=2.5) experiences damage at a rate that is approximately 50 percent greater than that of smooth pavement (PSI=4.0). With use of a walking beam tandem suspension, rough roads may experience damage as much as 3 times greater than that of smooth roads.

2.4 SPATIAL REPEATABILITY

According to Woodrooffe (1995), the significance of the pavement wear caused by heavy vehicle dynamic wheel loads depends to a great extent on the spatial correlation properties of wheel loads. Two wheel load signals are said to be spatially repeatable, or strongly correlated in the spatial domain, when their peaks and lows generally recur in the same locations along the road. Figure 2.6 illustrates this effect. Pavements are expected to wear significantly faster if wheel loads applied by different heavy vehicles are generally strongly correlated in the spatial domain, than if they are not.

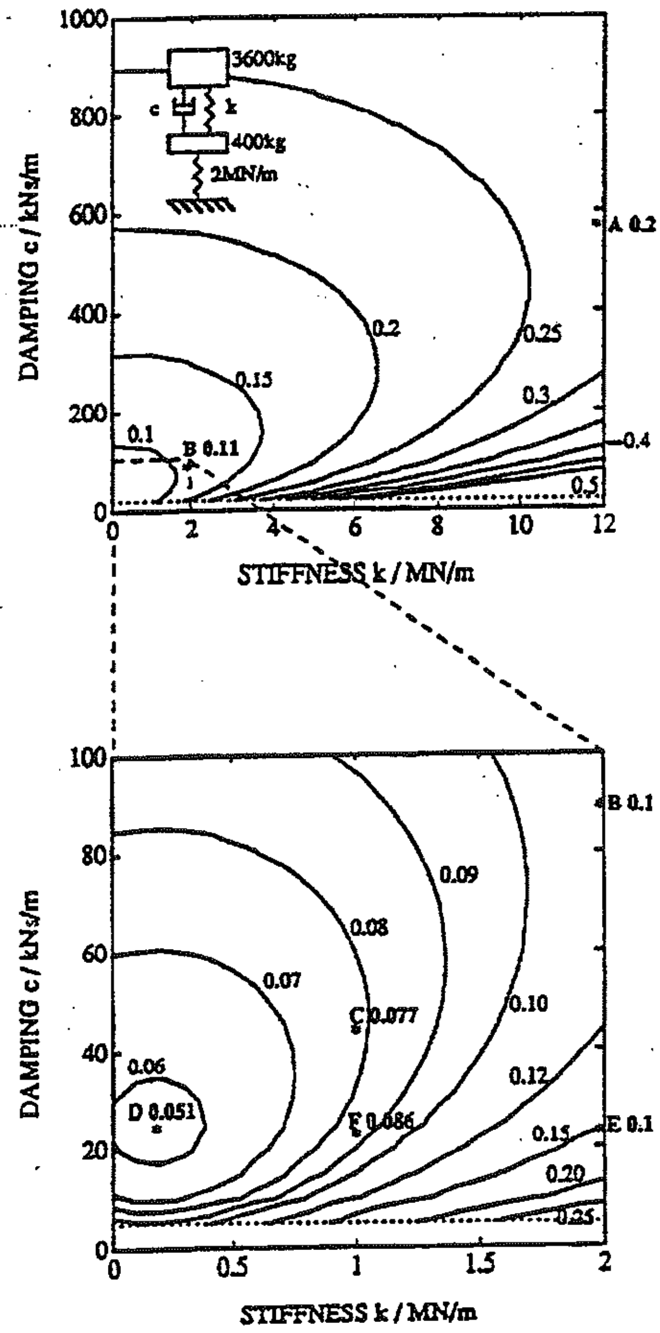


FIGURE 2.5 Contour of DLC as a Function of Suspension Stiffness and Damping (Cebon, 1999)

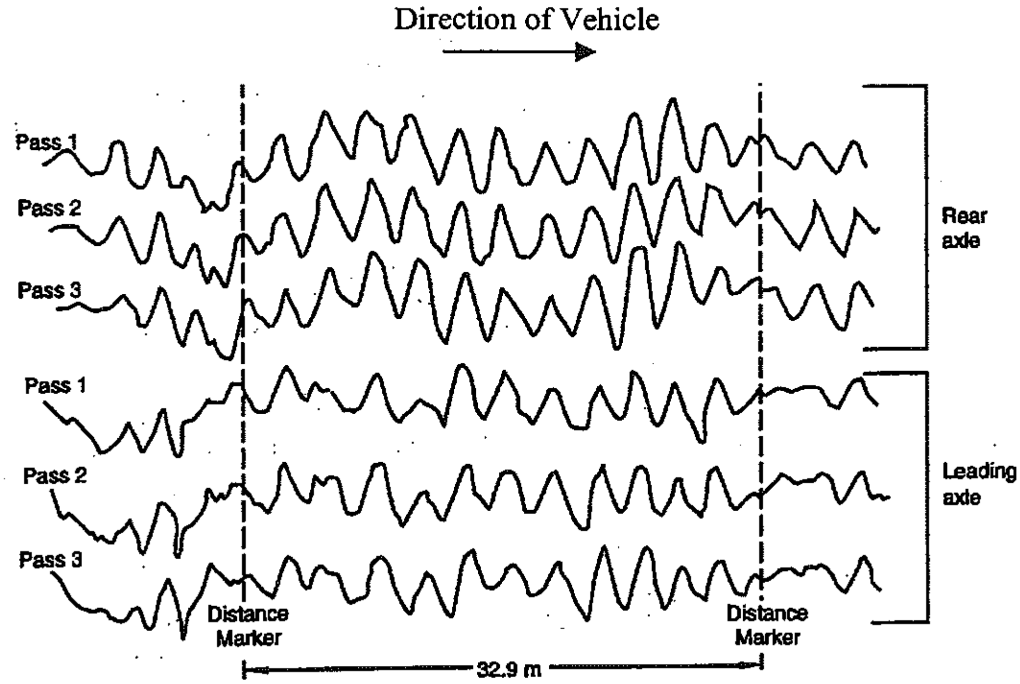


FIGURE 2.6 Measure of Dynamic Wheel Loads on Each Axle of a Leaf-Sprung Tandem for Three Separate Runs at 32 km/h (Cebon, 1999)

Hahn (1985) supported the spatial repeatability theory by saying that " Since all heavy commercial vehicles have approximately the same natural frequencies and are driven at approximately the same speed on motor ways and long distance roads, it may be concluded that for a given pavement the dynamic wheel load peaks always occur within relatively narrowly defined road sections."

Cebon (1987) suggested that road deterioration is governed by damage at the worst locations (95 percentile) rather than the average value over the road surface and so, dynamic wheel loads have significantly greater influence on pavement fatigue. Gillespie et al. (1991) analyzed dynamic loads using a 2-dimensional truck model. They concluded that dynamic tire forces based on mean damage level increases damage by 10 to 49 % relative to static loads; but if spatial repeatability is considered, damage increases typically by a factor of 2 to 4, and may reach 14-fold.

A heavy vehicle/pavement test was conducted at the PACCAR Technical Center to demonstrate spatial repeatability (Moran et al., 1995). Six test vehicles consisting of four tractor semi-trailers and two trucks were repeatedly driven over a ramp designed to excite the rigid body vibration modes. The results of this test showed that there were distinct areas of higher versus lower peak pavement strains, which remained consistent for all the vehicles tested. This result supports the spatial repeatability theory.

Woodrooffe et al.(1995) cited that spatial repeatability is sensitive to vehicle speed and suspension type. They conducted spatial repeatability tests using a research vehicle that consists of a three-axle tractor and three-axle trailer. In this test, they found that spatial correlation is highly sensitive to vehicle speed for walking-beam suspensions. A 10 km/h change in vehicle speed can cause spatial correlation coefficients to drop from 0.97 to 0.3. On the other hand, for air spring suspension, it is significantly less sensitive to changes in vehicle speed. The reason is that wheel loads for walking-beam suspensions are concentrated in a narrow frequency band.

Jacob (1995) reported differing results based on experimental data from the OECD's DIVINE road research project (1993-1995). From the results of this project, he reached a temporary conclusion that a good repeatability was shown for the same load configuration and same speed, but the spatial repeatability is lost when the speed varies. He explained this by the fact that on a good evenness the vibrations of the truck itself caused by a small local defect prevail over the effects of the evenness up to the next defect. In this case, he postulated that a frequency repeatability, rather than a spatial repeatability, is to be expected.

2.5 EFFECT OF DYNAMIC LOADS ON PERMANENT DEFORMATION

Plastic deformations are permanent deformations including all non-recoverable, irreversible deformations and viscous deformations. The basic mechanisms that make permanent deformations are densification of material and shear plastic deformation. Plastic deformations can occur in unbound materials as well as asphalt mixes. For unbound materials, the stress level and the number of load repetitions are important factors in determining the permanent deformations. Generally, the plastic strain is divided into three phases: Phase 1 of decreasing strain rate; phase 2 of constant strain rate; and phase 3 of accelerated strain rate. (Ullidtz, 1987)

Most pavement models use the first phase only. For the first phase, plastic strain is a function of load repetitions and stress level. It is approximated by (Ullidtz, 1988):

$$e_p = A \times \left(\frac{N}{10^6}\right)^B \times \left(\frac{\sigma}{p}\right)^C$$

where, A, B, and C are constants
N is number of load repetitions
σ is the compressive stress
p is a reference stress, usually atmospheric pressure ($p = 0.1$ MPa)

If the plastic strain exceeds a certain critical value, ε_o , the strain rate becomes constant (phase 2). For this phase, plastic deformation can be expressed by (Ullidtz, 1988);

$$\frac{\varepsilon_p}{\varepsilon_o} = 1 - B + B \times \left(\frac{N}{10^6}\right) \times \left[\frac{A}{\varepsilon_o} \times \left(\frac{\sigma}{p}\right)^C\right]^{\frac{1}{B}}$$

The value of A is a function of the elastic modulus of the soil. It can be calculated as :

$$A = 0.017 \times \left(\frac{50MPa}{E}\right)^{1.16C}$$

where, B and C are constants
E is the elastic modulus of the soil

The above equation says that in the first phase, permanent deformation is only a function of load repetitions and stress level; but in the second phase, it is a function of the elastic modulus.

According to the method developed by Shell (Hills et al., 1974), plastic strain in the asphalt is assumed to be purely viscous. And so, the plastic strain depends on the viscosity of bitumen and the accumulated loading time. Under this assumption, the plastic modulus of asphalt mixtures, E_p, has the following relationship with the viscosity of the bitumen (Ullidtz, 1988) :

$$E_p = A \times (3 \times \frac{v}{t_a})^B$$

where, v is the viscosity of the bitumen, N-sec/m^2
t_a is the accumulated loading time, sec
A and B are constants (A=70 to 90, B=0.3 to 0.5)

Approximate values of v can be obtained from:

$$v = 1.3 \times 10^{[3+(T_{RB}-T)/10]} \text{ N-sec/m}^2$$

where, T_{RB} is the Ring and Ball temperature, °C
T is the temperature in question, °C

Jordal and Rauhut (Huang, 1993, Jordal, 1983) predicted rut depth in pavement layers based on the assumption that the permanent strain is proportional to the resilient strain. The relationship is expressed as follows:

$$\varepsilon_p = \varepsilon\mu \frac{N^{1-\alpha}}{1-\alpha}$$

where, *m* and *a* are parameters
ε is the resilient strain at the 200th cycle

Gillespie et al.(1993) used the following model to predict rut depth in the AC layer. Permanent deformation at a particular point is obtained by:

$$z(x,\infty) = \int_{-\frac{x}{V}}^{\frac{x}{V}} h_\infty(V\theta) f(\frac{x}{V} - \theta) d\theta$$

where, $h_\infty(x)$: the rate of permanent vertical displacement of the road surface (similar to influence function)
V : vehicle speed
$f(t)$: the wheel load time history

Using this model, Gillespie calculated rut depths for different axle loads, suspension types, vehicle speeds, and so on. The results of this analysis indicated that the gross vehicle weight is the main determinant of rutting per vehicle pass. Suspension types do not have any significant effect on rut. The difference in rut damage caused by static loads and the damage at the locations suffering the most severe dynamic loading is generally only about 10 to 20 percent. This effect is significantly lower compared to that on fatigue damage that is up to a factor of 5 to 6 times the fatigue damage due to the static loads. These effects occur because of the high power in the fatigue damage. Rut depth is proportional to the magnitude of the wheel loads. The above results indicate that roughness of the pavement surface has no significant effect on rutting. However, spatial variations of dynamic loads translate into longitudinal permanent profile.

2.6 WHOLE-LIFE PAVEMENT PERFORMANCE MODEL

Collop and Cebon (1995) introduced a whole-life pavement performance model that attempts to predict damage due to traffic and environmental loading throughout the life of the pavement. This model is divided into three areas: 1) dynamic vehicle simulation, 2) pavement primary response simulation, and 3) material damage simulation.

The main concept of this model is that road roughness generates dynamic vehicle loads. These dynamic loads in turn cause damage (rutting and fatigue) in pavements. Rutting (permanent deformation) changes road surface profile and fatigue damage reduces the elastic modulus of the asphaltic material. The updated surface profile and elastic modulus are then used in the dynamic vehicle simulation model and in pavement damage calculations for the next time interval. Figure 2.7 shows a flowchart for the whole-life pavement performance model (Cebon, 1999).

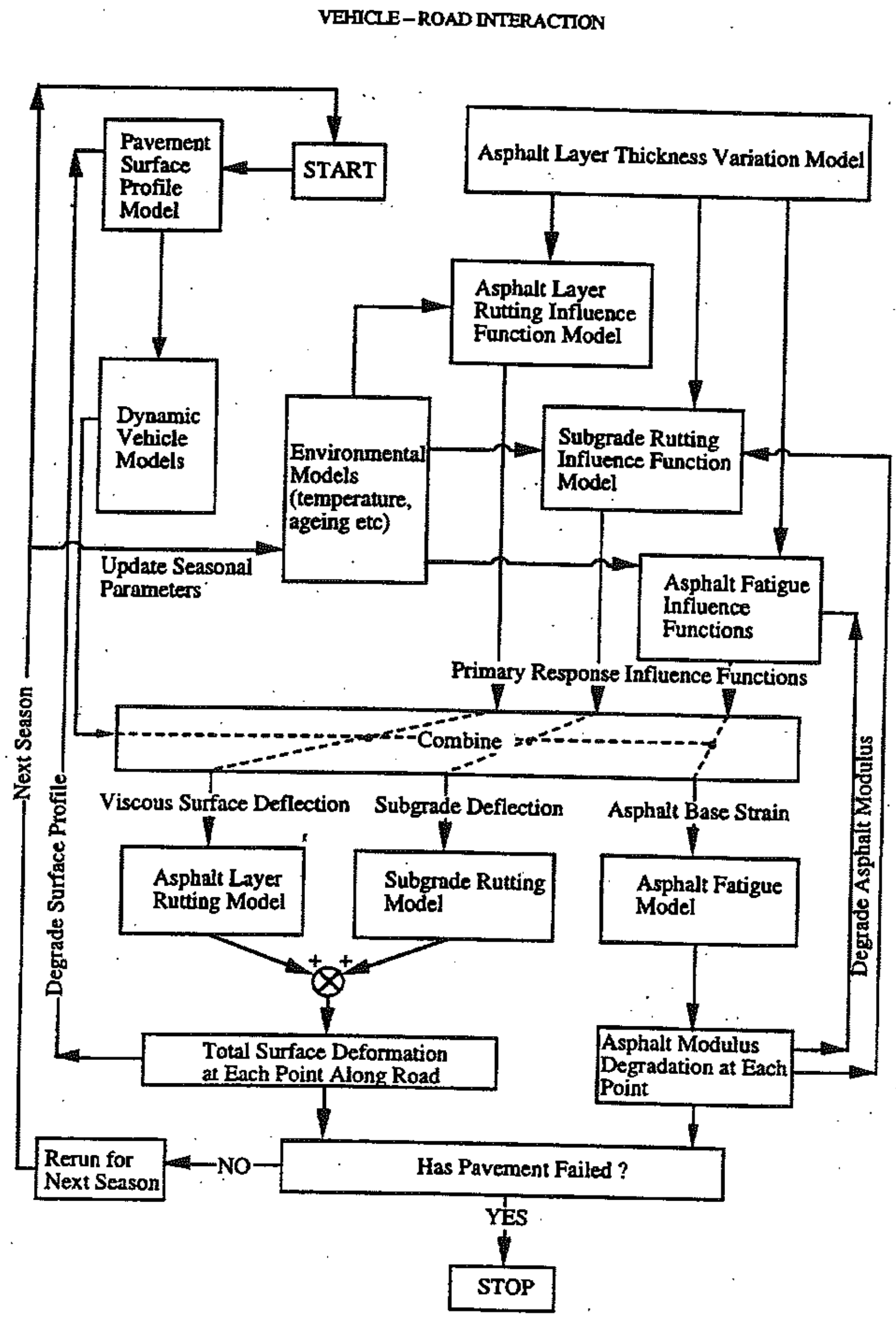


FIGURE 2.7 Whole-Life Pavement Performance Model Methodology (Cebon, 1999)

In this model, the pavement surface profile spectral density is obtained,

$$Sz(r) = cr^{-w} \qquad (0<r<r_{max})$$

where r is the wavenumber (cycles/m), $w = 2.5$, and c is a constant corresponding to road type.

A surface displacement history is generated from the above equation by applying a set of random phase angles, uniformly distributed between 0 and 2π, to a series of coefficients derived from the desired spectral density and applying the inverse Fast Fourier Transform.

For fatigue prediction, conventional fatigue model and Miner's hypothesis of linear damage accumulation were used,

$$N_f^i = k_1 \varepsilon_i^{-k2}$$

$$D = \sum_{i=1}^{j} \frac{N^i}{N_f^j}$$

where D is an accumulation of fatigue damage, N^i is the number of cycles of strain level ε_i, N_f^i is the number of cycles to failure at strain level i and k is the number of different strain levels.

A simple relationship between vertical subgrade strain and permanent deformation was used to predict rutting in the subgrade and granular layer.

$$\delta_i = L_i \varepsilon_i^{L2}$$

where δ_i is the incremental vertical permanent deformation in the subgrade and granular layer due to vertical subgrade compression strain ε_i, and L_1 and L_2 are material constants.

From surface deflection data obtained from Accelerated Loading Facility (ALF) trials and backcalculation, they obtained a function between the modulus and the cumulative fatigue damage as shown below,

$$E/E_o = e^{KD} \qquad D<1,$$
$$E/E_o = (E/E_o)_c \qquad D\geq 1,$$
$$K = \log_e(E/E_o)_c$$

where E/E_o is the reduction in elastic modulus of the asphaltic material, D is the cumulative fatigue damage and $(E/E_o)_c$ is a constant that determines the level of modulus reduction corresponding to the end of fatigue life for the asphalt mix.

CHAPTER 3
CORRELATING SURFACE ROUGHNESS, DYNAMIC LOADING AND PAVEMENT DISTRESS USING FIELD DATA: A CASE STUDY

Summary

The relationship between load and distress is complex, and is not well understood to this date. The variability in pavement materials, environmental and traffic factors, coupled with errors in field measurements and the subjectivity of the field distress surveys make it extremely hard to relate roughness and dynamic loading to the accumulation of pavement distress in in-service pavements. Furthermore, some distresses are mainly material- or environment- related. To show how one could use roughness and distress data together for the purpose of discerning between cases of load-related distress accumulation and other non-load-related distress accumulation, several analyses on distress and roughness were done.

Plotting roughness and distress profiles along the project length allows for identifying zones of high distress and/or high roughness. Combining the above information with the trends of distress and roughness indices from year to year allows for discerning dynamic load-related from non-load-related distress accumulation. This chapter shows examples of different scenarios encountered for the three pavement types, namely rigid, flexible and composite. Comparison of dynamic-load and distress-point profiles along the length of a given pavement section enabled the assessment of the reasonableness of the ρ-values relating the two profiles. The results showed that a reasonably good match (from an engineering point of view) between load and distress profiles is possible with relatively low ρ-values (between 0.25 and 0.5) whereas a ρ-value that is less than 0.2 is indicative of a poor match. A higher ρ-value indicates dynamic load-related distress accumulation, and a lower ρ-value indicates that the distress accumulation is not primarily related to dynamic loading.

Finally, combining plots of distress, roughness and dynamic load trends with time can give a good indication on whether distress is load related or not.

3.1 INTRODUCTION

Dynamic wheel loads are generated by road roughness. The amplitude of dynamic loading is a function of road surface profile and vehicle parameters including suspension, tire, body mounts and vehicle speed. These (higher) dynamic axle loads increase pavement damage, which in turn translates to a rougher surface. Pavement deterioration is therefore a result of this interaction between the pavement and trucks. However, the relationship between dynamic loading and pavement distress is complex, and is not well understood to this date. The variability in pavement materials, environmental and traffic factors, coupled with errors in field measurements and the subjectivity of the field distress surveys make it extremely hard to relate roughness and dynamic loading to the accumulation of pavement distress in in-service pavements. Therefore any interpretation of field data must be made with extreme caution.

Many researchers studied the effect of dynamic truck loading on pavement damage. There have been two main approaches to estimating the road-damaging effects of dynamic loads. The first, developed by Eisenmann, assumes that dynamic wheel loads form a stochastic process, i.e., loads are randomly applied to each point along a given stretch of a road. As a result, each point incurs loads that are statistically similar to other points along the same road, and therefore, induce uniformly distributed road damage (Eisenmann, 1975). The second approach assumes that the phenomenon of "spatial repeatability" applies to normal traffic conditions. This phenomenon was observed by several researchers in field tests involving instrumented trucks (Cebon, 1999). It states that for a given speed, the dynamic wheel-load time histories generated by a particular heavy vehicle are concentrated and repeated closely at specific locations along the road on successive truck runs (Gillespie et. al., 1993). Since a large portion of heavy vehicles have similar geometry and dynamic characteristics and tend to travel at similar highway speeds, spatial repeatability of dynamic loadings is expected in normal traffic conditions (Mrad et. al. 1997).

In this chapter, the analysis was done on spatial repeatability of dynamic axle load was analyzed using three different truck types and real pavement profiles. Based on the findings of this analysis, the 2nd axle load in a 5-axle semi-trailer was determined to be representative of the three truck types used. This "reference" axle was then used in developing relationships between RQI and dynamic load (chapters 3 and 5) as well as a new roughness index and in the calculation of pavement life extension (chapter 6). An attempt was also made to show how one could use roughness and distress data together for the purpose of discerning between cases of load-related distress accumulation and other non-load-related distress accumulation.

3.2 SITE SELECTION

The first stage of the study involves the analysis of roughness and distress data from a limited number of actual pavement projects in Michigan. The MDOT Technical Advisory Group (TAG) was given the task of selecting ten sites with known performance records and having exhibited some distress in the time period between 1992 and 1997. The reason for choosing this period is that roughness and distress data are not available outside this window. The MSU research team was not to have any background information on the selected sites in order to maintain an unbiased approach to analyzing the data. The task given to the research team was to investigate the relationship between road surface roughness and pavement distress, if any, and to develop possible scenarios for each of the pavement sites. Ten sites were selected, including interstate and US highways in the State of Michigan. Five of the ten sites were rigid pavements, three were flexible pavements with rubblized concrete bases, and two were composite pavements. The selected sites are listed in Table 3.1 along with some pertinent information.

TABLE 3.1 List of Projects Investigated

Route	Control Section	Pavement Type	BMP	EMP	Construction Date
EB US-10	09101	Flexible(Rubblized PCC base)	0.92	7.37	8/90
EB I-96	33084	Flexible(Rubblized PCC base)	8.98	17.49	10/93
NB US-23	47014	Flexible(Rubblized PCC base)	0.00	7.17	10/92
EB I-69	76024	Rigid	0.00	3.83	7/91
EB I-94	11017	Rigid	1.02	5.88	9/95
NB I-69	23063	Rigid	0.00	5.00	11/91
EB US-10	18024	Rigid	0.00	7.60	11/76
WB US-10	18024	Rigid	0.00	7.60	11/76
EB I-94	38101	Composite	0.00	8.70	10/85
NB US-127	38131	Composite	0.00	5.20	10/87

3.3 DATA COLLECTION

For the ten selected sites, DI and RQI data as well as road surface profiles were obtained from the MDOT PMS database. DI values were available for 1993, 1995 and 1997; whereas RQI values and road profiles were available for the period between 1992 and 1996. The DI and RQI data were available for 0.1-mile sections. Surface profile data were converted to ASCII files containing surface elevations at 3-in intervals. In addition, detailed distress data in the form of distress type, severity and extent was also available to the research team at 10-ft intervals. The data were converted to Distress Points (DP) as described in Chapter 1.

3.4 DATA ANALYSIS

3.4.1 Relationship between RQI, IRI and DLC

For each pavement section (total number of sections from the ten projects is 168), IRI-values were calculated using the RoadRuf© computer program. RQI-values were plotted against the calculated IRI-values, as shown in Figure 3.1 (a). As expected, RQI and IRI have a good correlation, with the RQI increasing asymptotically with increasing IRI to a plateau value of about 100 as the IRI-values approach the 4 to 5 mm/m (250 to 300 in/mi) range. The IRI-value corresponding to an RQI of 70 is about 2.4 mm/m (150in/mi). A standard 18-wheel tractor-semitrailer was run over each of the selected 0.1-mile sections at normal traffic speed. The static front axle load is 12,000 lb and the drive and rear tandem axle loads are 34,000 lb. The axles are equipped with standard leaf-spring suspensions. The TruckSim™ program was used to generate dynamic loads. Dynamic Load Coefficients (DLC) were then calculated. DLC is a dimensionless measure of dynamic variation of an axle load, and is calculated as the ratio of the standard deviation over the mean static load. The DLC-values reported herein correspond to those from the front drive axle. DLC, RQI and IRI -values were plotted in Figure 3.1 (b) and (c). The figure shows good fits between these indices, indicating that both roughness indices can be reasonably good general indicators for dynamic loading and future pavement deterioration.

3.4.2 Correlation between Dynamic Loads from Different Axles and Trucks

The TruckSim™ program was used to generate dynamic axle loads from three truck types: 2 and 3-axle single unit trucks and a 5-axle tractor semi-trailer. Truck configurations and suspension properties used in the simulation are shown in Tables 3.2 and 3.3, respectively.

To investigate spatial repeatability of dynamic loads for all truck axles, the correlation between the different axles were studied. Figure 3.2 shows coefficients of correlation (ρ) between profiles for each axle load and those for the reference axle load (2nd axle load in 5-axle semi-trailer) within each section. The figure shows variable degrees of correlation among different axles. The best correlations are among the drive axles from the three trucks while the worst is with the rear axle of the tractor semi-trailer, indicating that the trailer is out-of phase with the tractor. The correlation between aggregate axle loads for the different trucks is strong (see Figure 3.3) with coefficients of correlation higher than 0.77. Cole (1990) has shown that a ρ-value of 0.707 is indicative of good spatial repeatability. Aggregate axle loads for each truck and the reference axle load show very good correlation with values around 0.7 (see Figure 3.4). This indicates that the reference axle can be used to represent the aggregate load from all trucks.

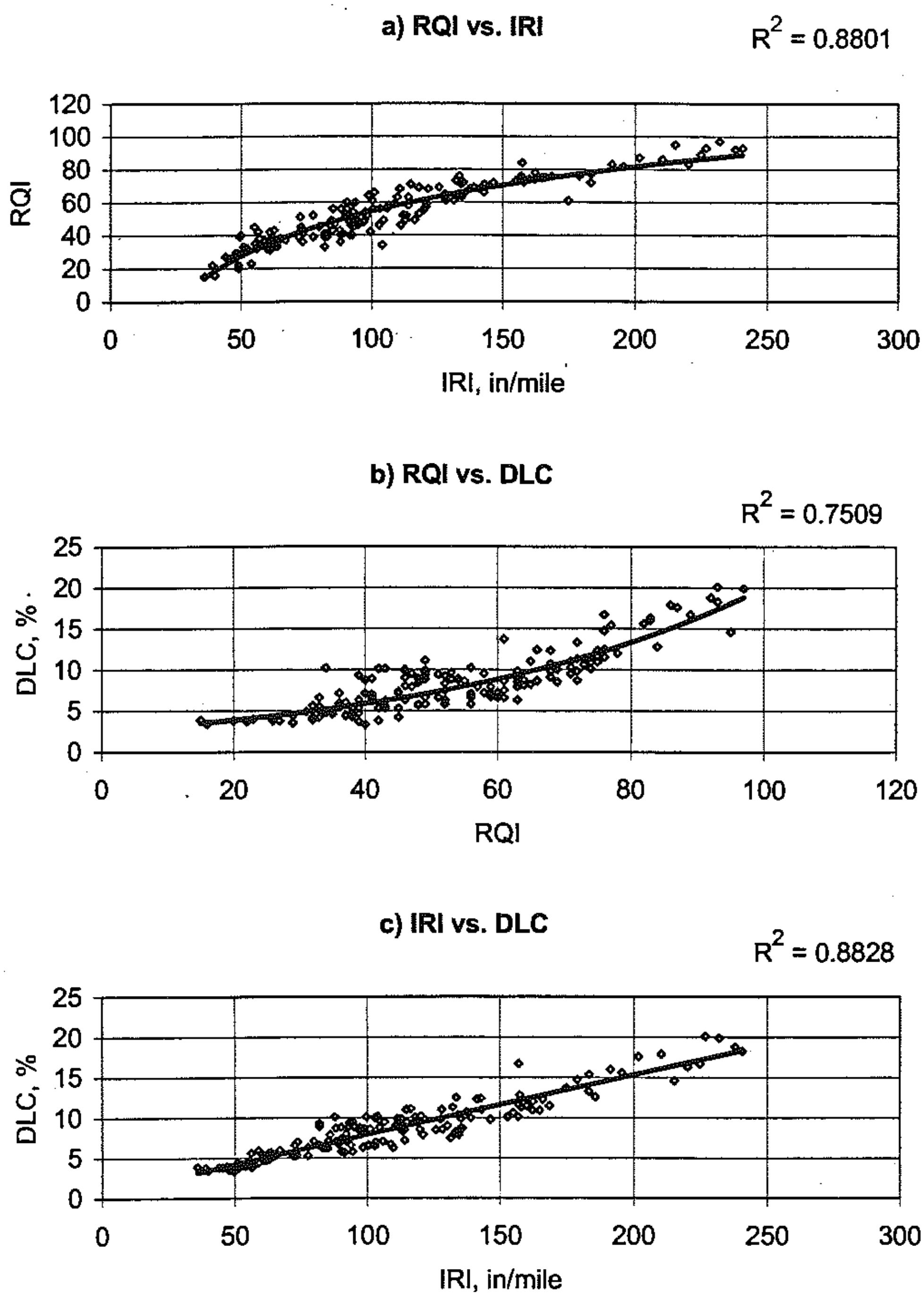


FIGURE 3.1 Relationships between RQI, IRI and DLC

TABLE 3.2 Truck Matrix Sizes and Weights

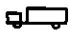
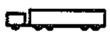
Truck Configuration	Configuration Name	GCVW (kN)	Axle Loads (kN)	Wheel Base (m)
	2 Axle Truck	125	49/76	4.3
	3 Axle Truck	150	56/94	6.1
	5 Axle Semi-Trailer	356	54/151/151	3.6/11.0

TABLE 3.3 Suspension Vertical Properties

Suspension Location	Suspension Type	Upper Envelope Stiffness (kN/m)	Lower Envelope Stiffness (kN/m)	β	Linear Damping Coefficient (kN-s/m)	Unsprung Weight (kN)
Steer Axle	Flat Leaf	28.5	28.5	0.04	0.50	6.2
Single Drive Axle	Flat Leaf	47.8	41.3	0.08	0.02	11.1
Tandem Drive Axle	Flat Leaf	47.8	41.3	0.08	0.02	22.7
Tandem Semi-trailer Axle	Flat Leaf	47.8	41.3	0.08	0.02	16.9

β ≡ Decay Constant

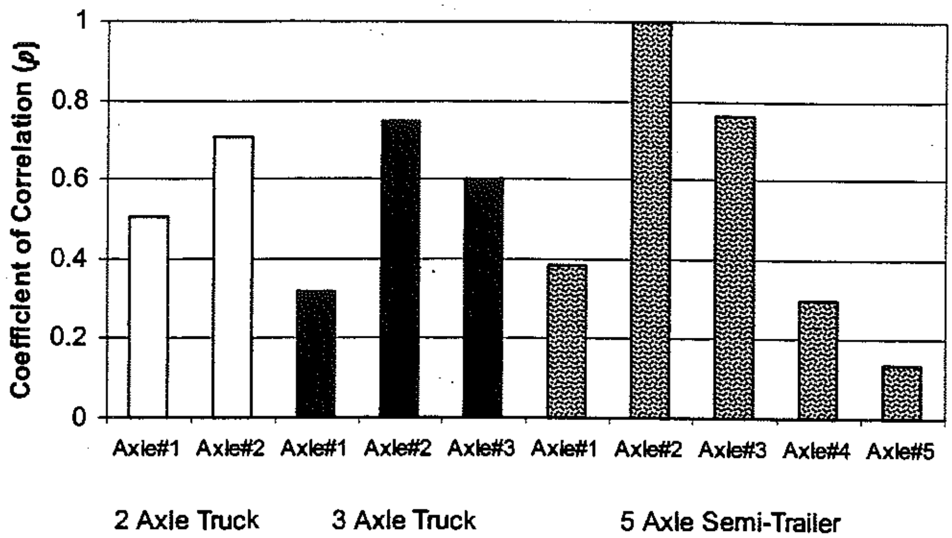


FIGURE 3.2 Coefficient of Correlation between various Axle Loads and the Reference Axle Load (2nd Axle Load of 5-Axle Semi-Trailer)

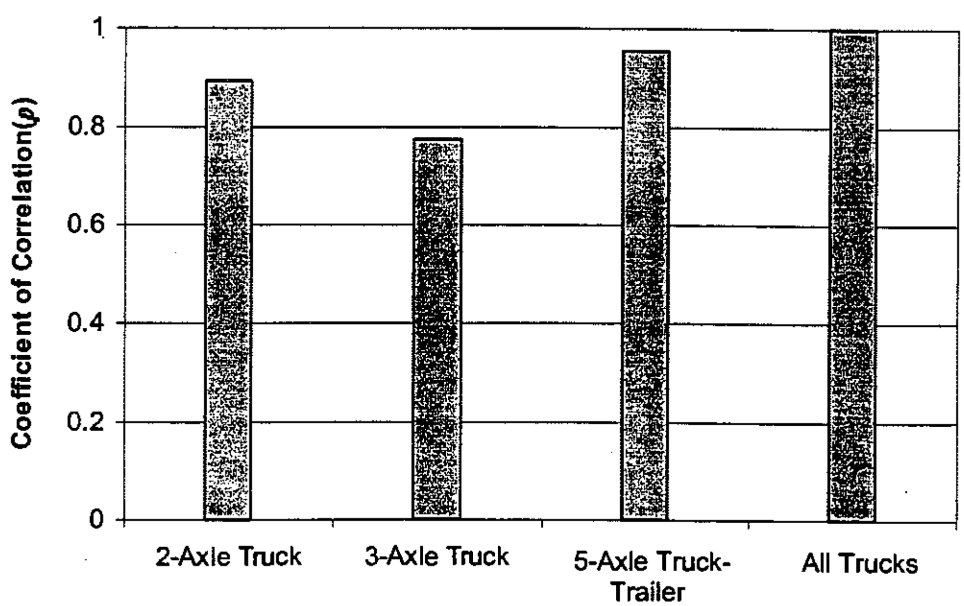


FIGURE 3.3 Coefficient of Correlation between Aggregate Axle Loads of Each Truck and Aggregate Axle Load from All Trucks

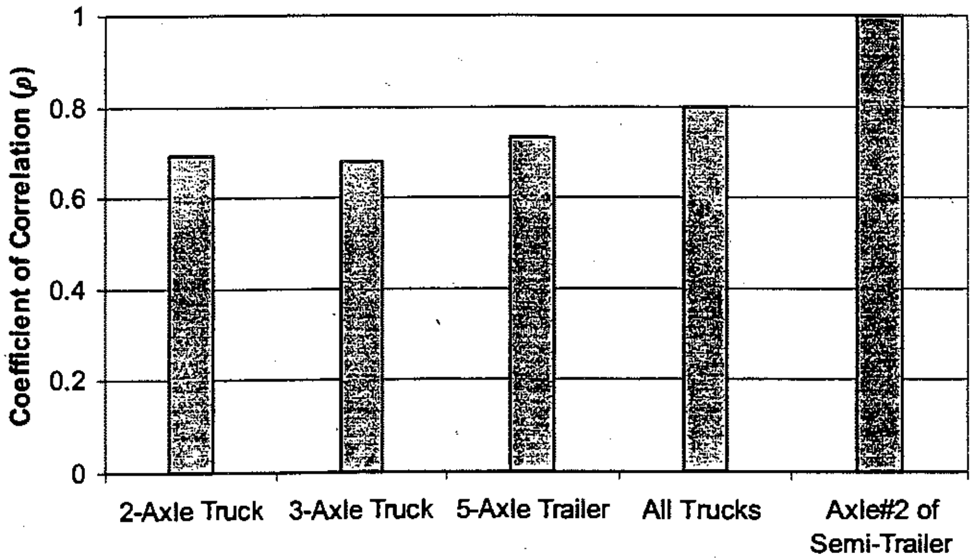


FIGURE 3.4 Coefficient of Correlation between Aggregate Axle Load of Different Trucks and the 2nd Axle Load of the 5-Axle Semi-Trailer

3.4.3 Distress and Roughness Profiles

DI and RQI data for all ten sites were normalized with respect to their respective threshold values of 40 and 70, and plotted along the longitudinal direction. The threshold values correspond to the lower limit of the high level range, as categorized by the MDOT PMS. These plots, which were generated for 1993, 1995 and 1997, give an overall view of DI and RQI levels for the entire project length in a given site. Figures 3.5, 3.6, 3.7 and 3.8 show examples of such plots. These plots for the other projects are in Appendix G.

3.4.4 Distress, Roughness and Dynamic Loading Trends with Time

Comparison of DI and RQI profiles allows for identifying sections of high distress and/or high roughness levels. From each site, four 0.1-mile sections were selected for further analysis. These sections included cases of "high distress - high roughness", "high distress - low roughness" and "low distress - high roughness." For each 0.1-mile section, IRI values were calculated using the RoadRuf® computer program (developed by UMTRI). Figure 3.1 (a) shows the relationship between RQI and IRI and it indicates that the IRI value corresponding to an RQI value of 70 is about 150 in/mi. This value was chosen as the threshold IRI value by which IRI data will be normalized in subsequent analysis. Figure 3.1(b) and Figure 3.1(c) show the relationships between DLC and RQI and IRI, respectively. The figures show good correlations, with RQI of 70 and IRI of 150 corresponding to a DLC of 12%. This value was chosen as the threshold DLC-value by which DLC data will be normalized. Normalized DI, RQI and IRI, and DLC values for each subsection were plotted at consecutive years. Figures 3.9, 3.10, 3.11 and 3.12 show examples of such plots. Same plots for the other sections selected are in Appendix G.

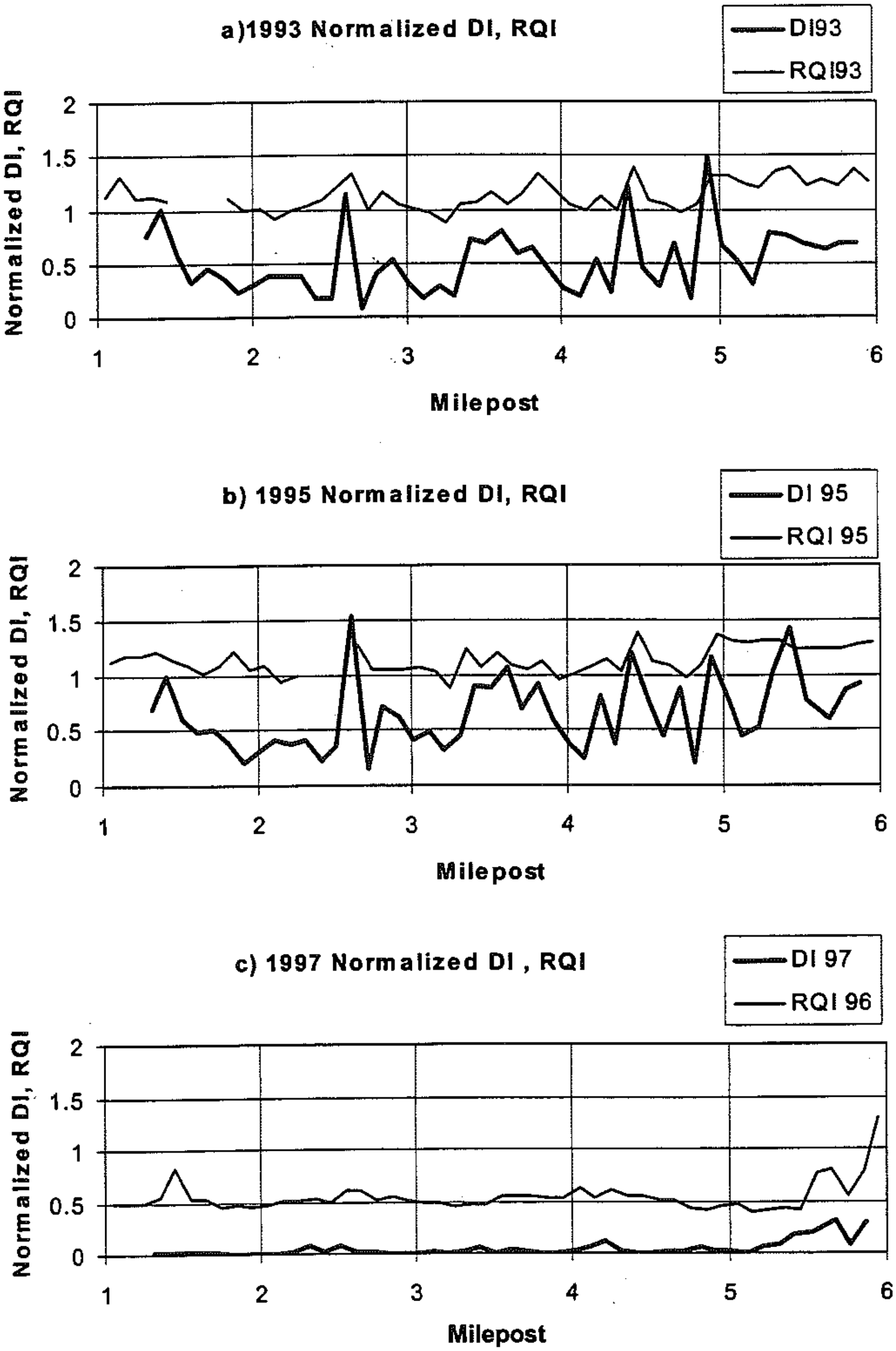


FIGURE 3.5 Distress and Roughness Profiles along the Project Length for EB I-94 (CS 11017) MP 1.02 to 5.88

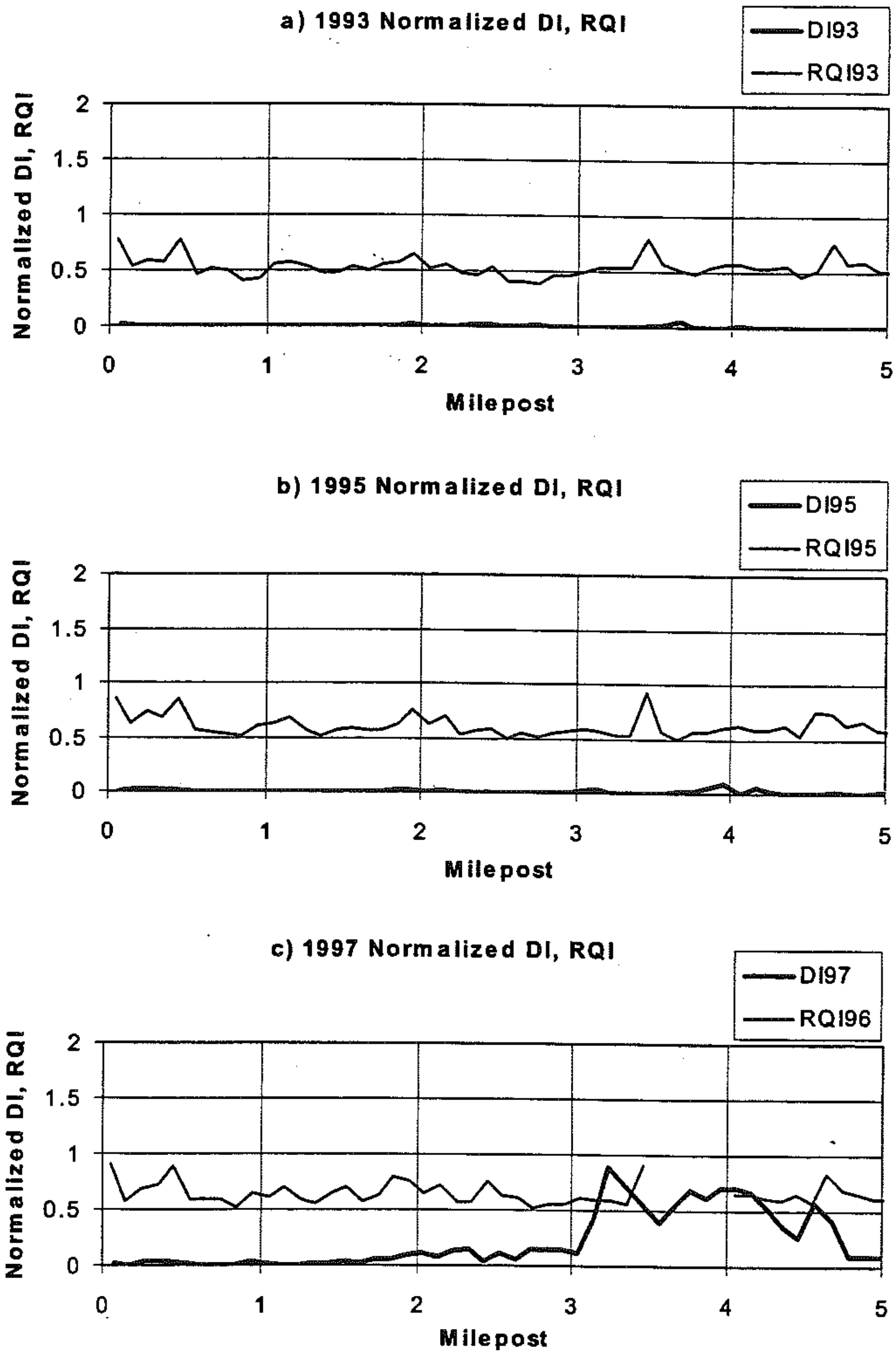


FIGURE 3.6 Distress and Roughness Profiles along the Project Length for NB I-69 (CS 23063) MP 0.0 to 5.0

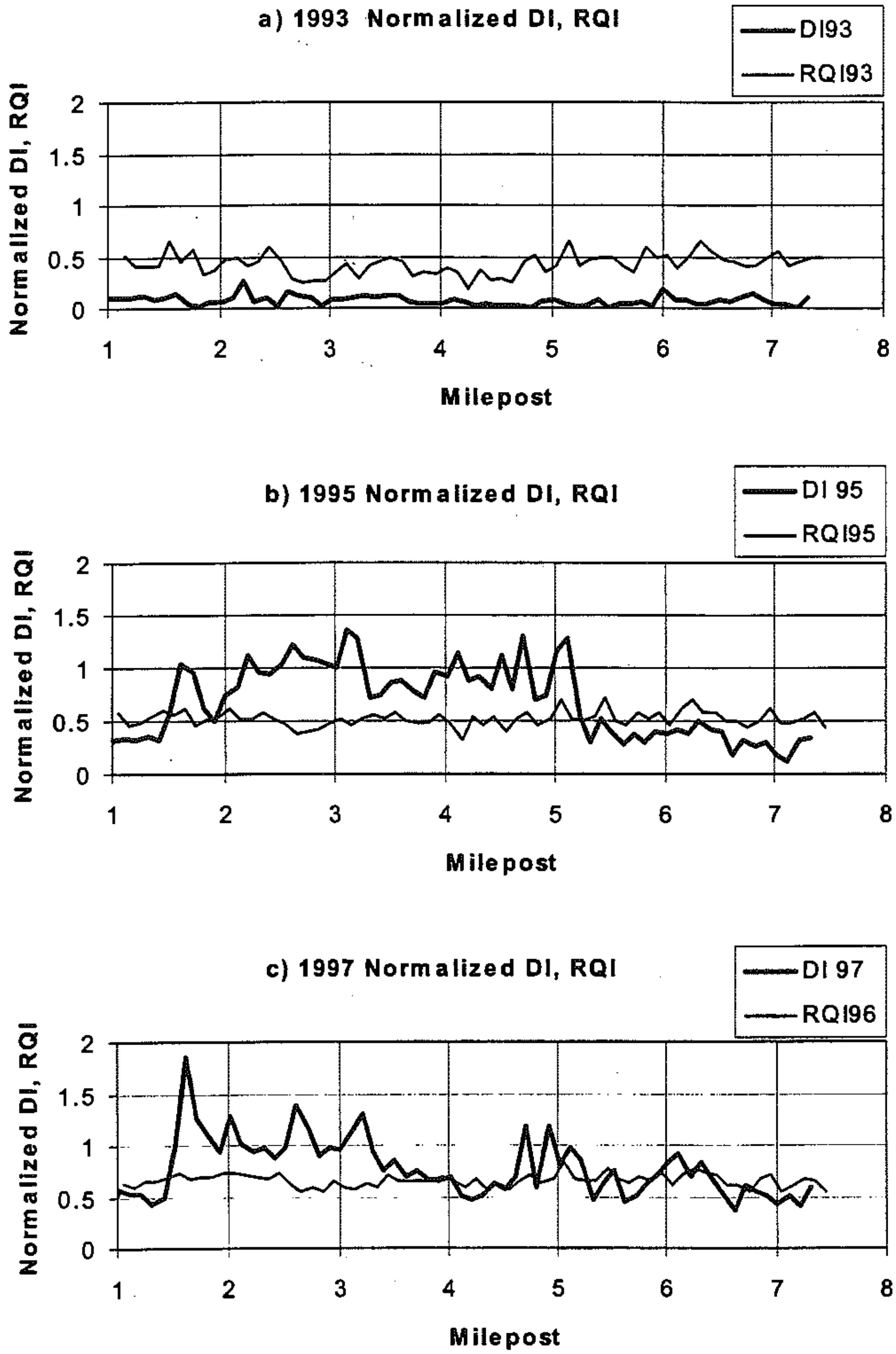


FIGURE 3.7 Distress and Roughness Profiles along the Project Length for EB US-10 (CS 09101) MP 0.924 to 7.356

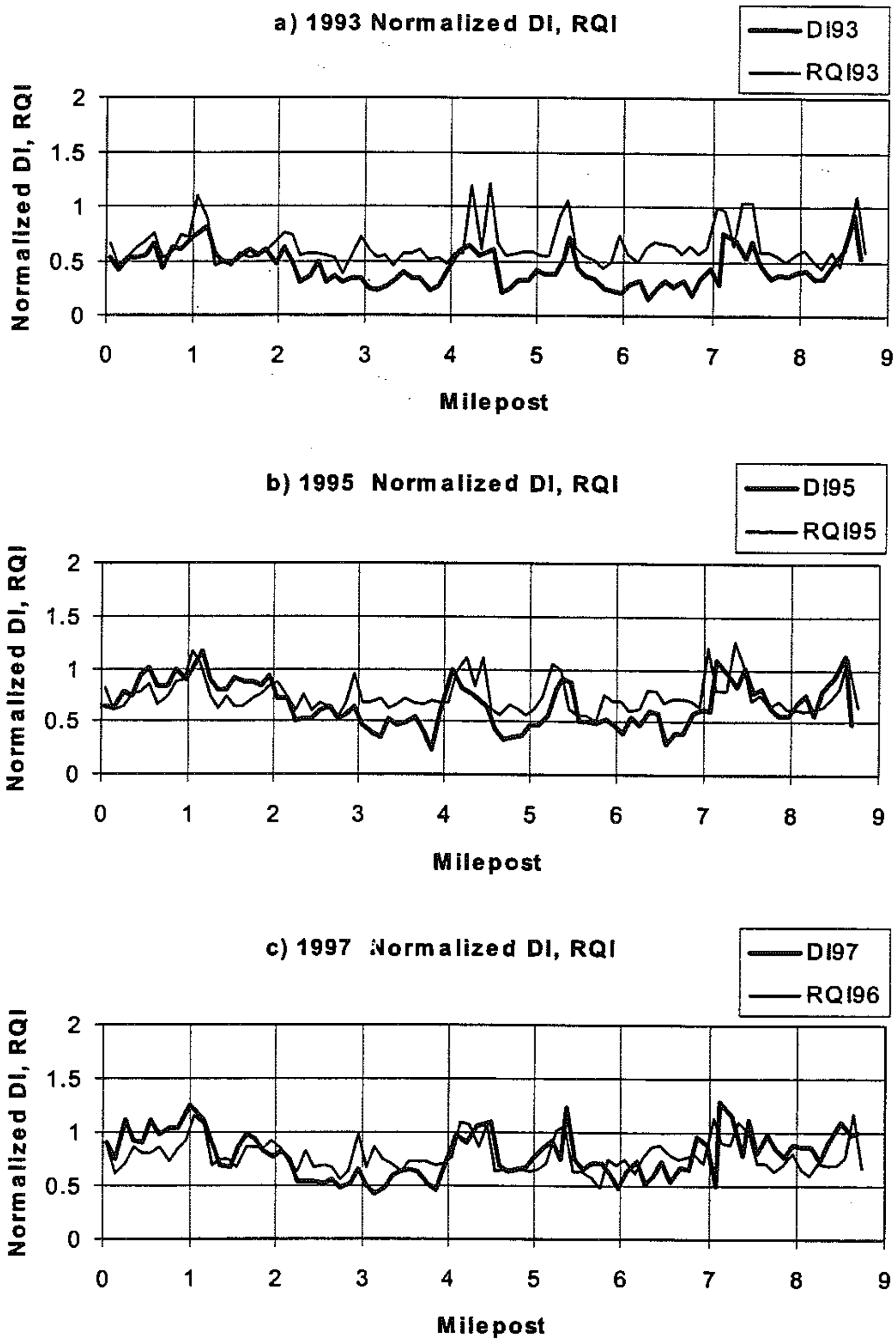


Figure 3.8 Distress and Roughness Profiles along the Project Length for EB I-94 (CS 38101) MP 0.0 to 8.7

3.4.5 Distress Point and Dynamic Loading Spatial Distribution

To further confirm whether the distress is load-related or not, one can plot the distribution of Distress Points (DP) along the 0.1-mile long section against that of the dynamic load (DL). This was done for all sections, and Figures 3.13, 3.14, 3.15 and 3.16 are examples of such plots. Both DP and DL values have been normalized with respect to their respective 95th percentile value, which should represent the more severe cases of distress accumulation and dynamic load amplification, respectively. A Coefficient of Correlation (ρ) between DL and DP was calculated for each subsection. Figure 3.17 shows all ρ-values for rigid, flexible and composite pavement sections. While these ρ-values appear to be low, it will be shown in the next section that a reasonable overall match between dynamic loading and pavement distress can be obtained in spite of a relatively low ρ-value. The plots of distress points against corresponding dynamic load for the other sections selected are shown in Appendix G.

3.4.6 Interpretation of the Results

The relationship between load and distress is complex, and is not well understood to this date. The variability in pavement materials, environmental and traffic factors, coupled with errors in field measurements and the subjectivity of the field distress surveys make it extremely hard to relate roughness and dynamic loading to the accumulation of pavement distress in in-service pavements. Furthermore, some distresses are mainly material- or environment- related. In addition, there are always field situations where a particular condition arises, causing a premature occurrence of distress or a sudden acceleration thereof. Therefore any interpretation of field data must be made with extreme caution.

In this chapter, an attempt has been made to show how one could use roughness and distress data together for the purpose of discerning between cases of load-related distress accumulation and other non-load-related distress accumulation. The three types of profiles described above are used simultaneously to arrive at a particular observation. Given the limited number of sites studied and the bias that may have been introduced in the selection of the pavement sites, the discussion herein is limited to showing examples of a good match versus a poor match between surface roughness, dynamic loading and pavement distress. A good match should correspond to a case of mostly load-related distress accumulation; whereas a poor match would most likely correspond to mostly material- or environment- related distress accumulation. It should be noted that in both cases, one or the other cause of distress would be partly responsible for the progression of distress. Four example sites were chosen to illustrate the above:

- Examples of good and poor matches between roughness and distress in rigid pavements
- An example of a poor match for flexible pavements
- An example of a good match for composite pavements

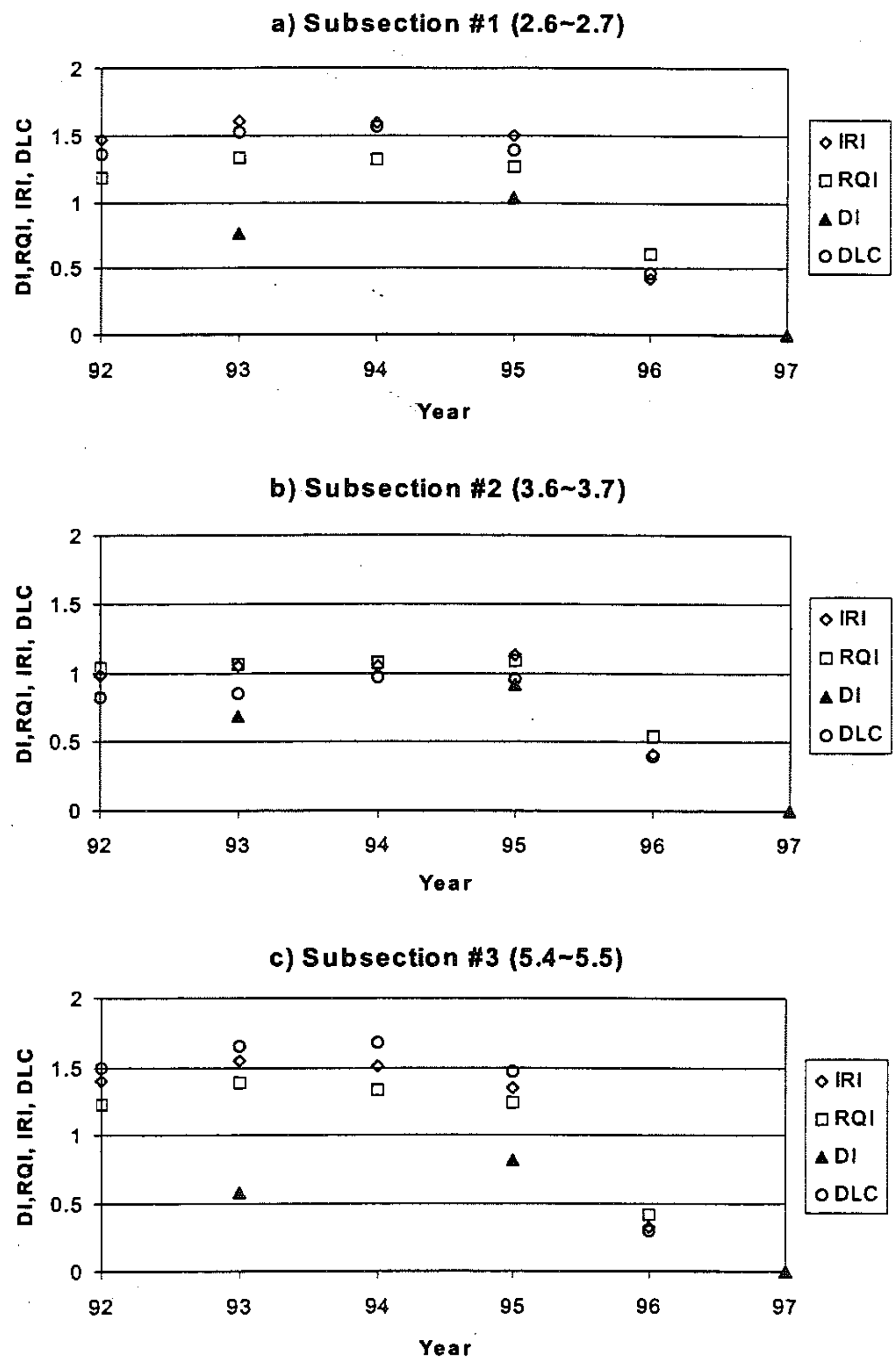


Figure 3.9 Year-to-Year Trend of Roughness, Distress and Dynamic Loading Indices for Three 0.1 Mile Subsections along EB I-94 Project (CS 11017)

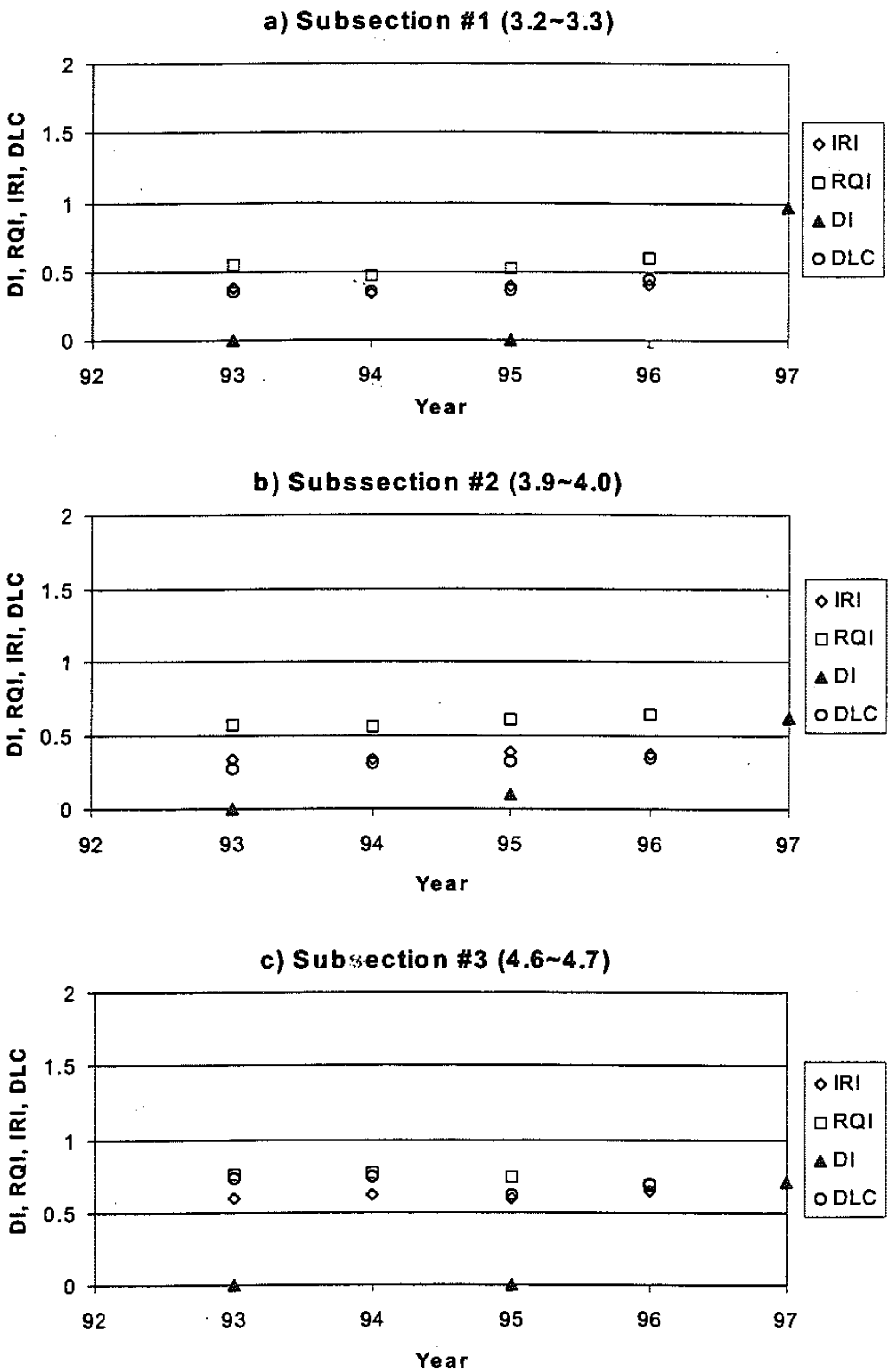


FIGURE 3.10 Year-to-Year Trend of Roughness, Distress and Dynamic Loading Indices for Three 0.1 Mile Subsections along NB I-69 Project (CS 23063)

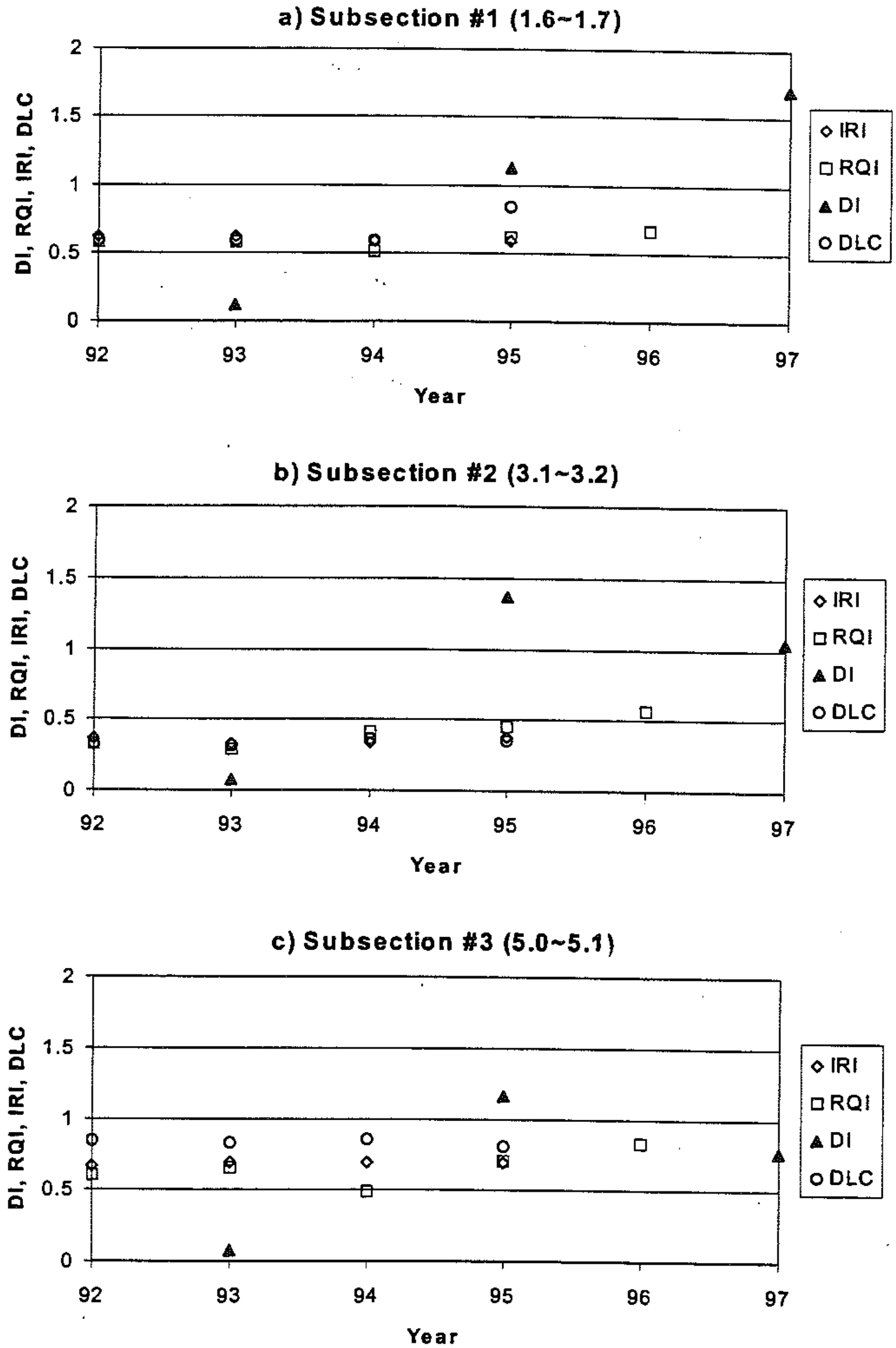


FIGURE 3.11 Year-to-Year Trend of Roughness, Distress and Dynamic Loading Indices for Three 0.1 Mile Subsections along EB US-10 Project (CS 09101)

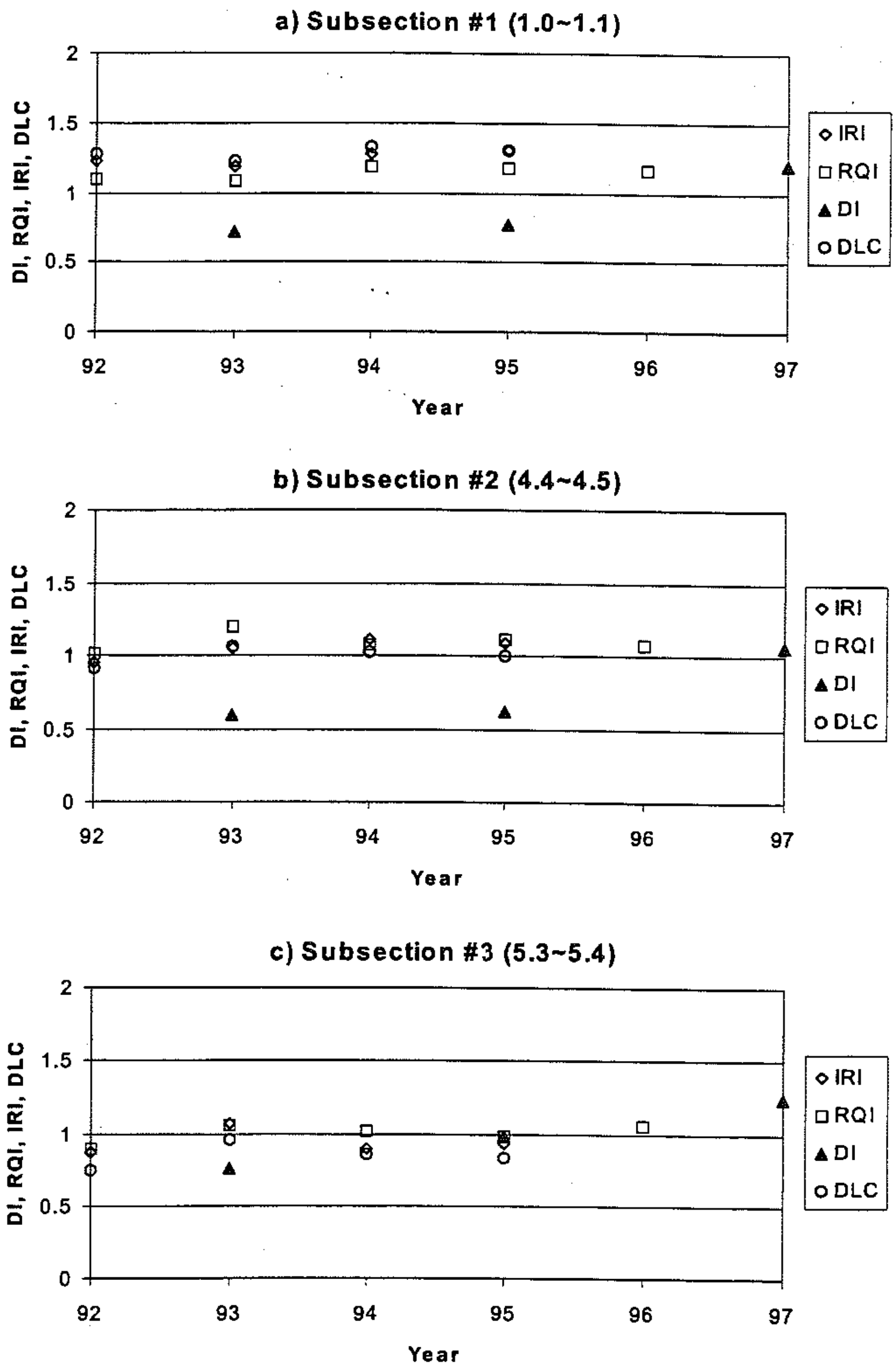


FIGURE 3.12 Year-to-Year Trend of Roughness, Distress and Dynamic Loading Indices for Three 0.1 Mile Subsections along EB I-94 Project (CS 38101)

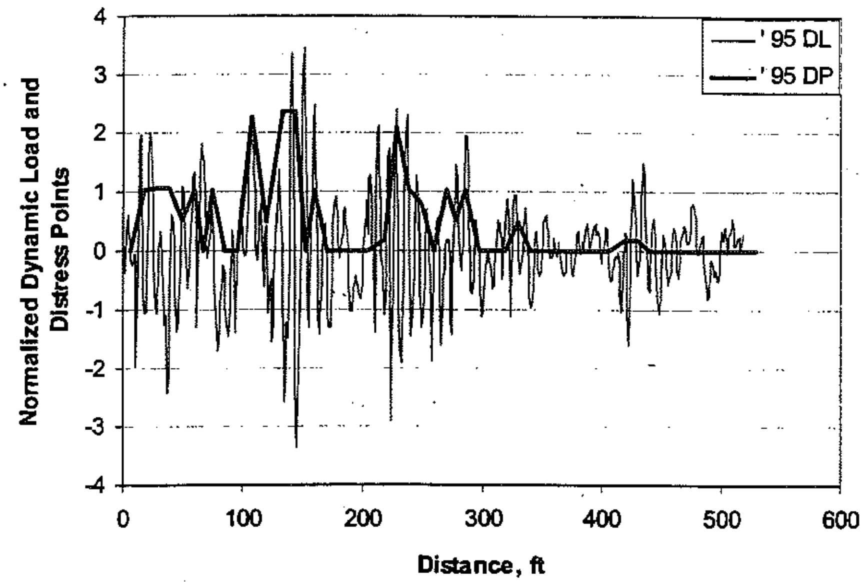


FIGURE 3.13 Normalized Dynamic Load and Distress Points versus Longitudinal Distance along Subsection #1 (MP 2.6 to 2.7) of EB I-94 Project (CS 11017)

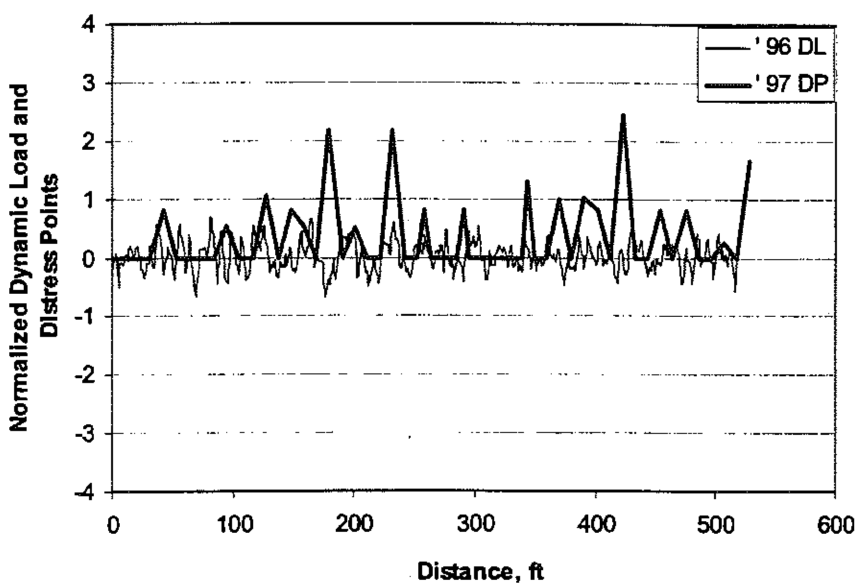


FIGURE 3.14 Normalized Dynamic Load and Distress Points versus Longitudinal Distance along Subsection #1 (MP 3.2 to 3.3) of NB I-69 Project (CS 23063)

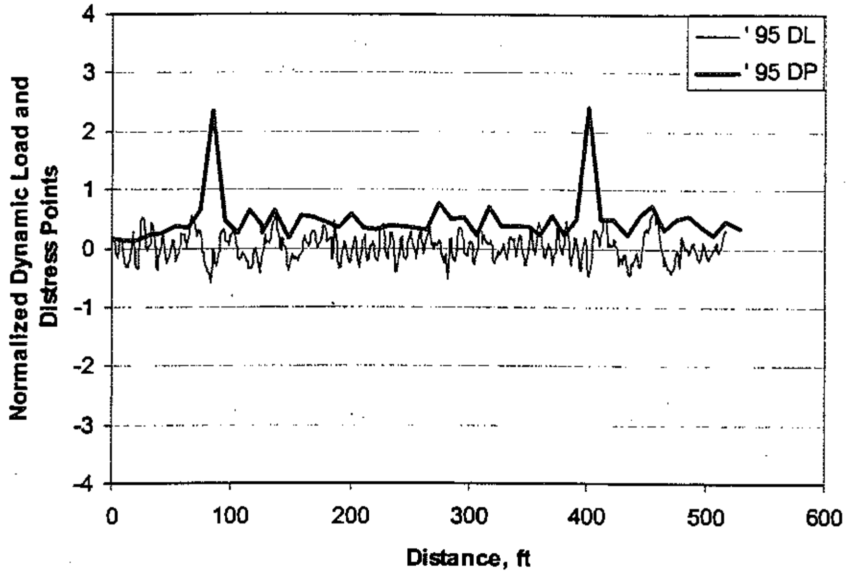


FIGURE 3.15 **Normalized Dynamic Load and Distress Points versus Longitudinal Distance along Subsection #2 (MP 3.1 to 3.2) of EB US-10 Project (CS 09101)**

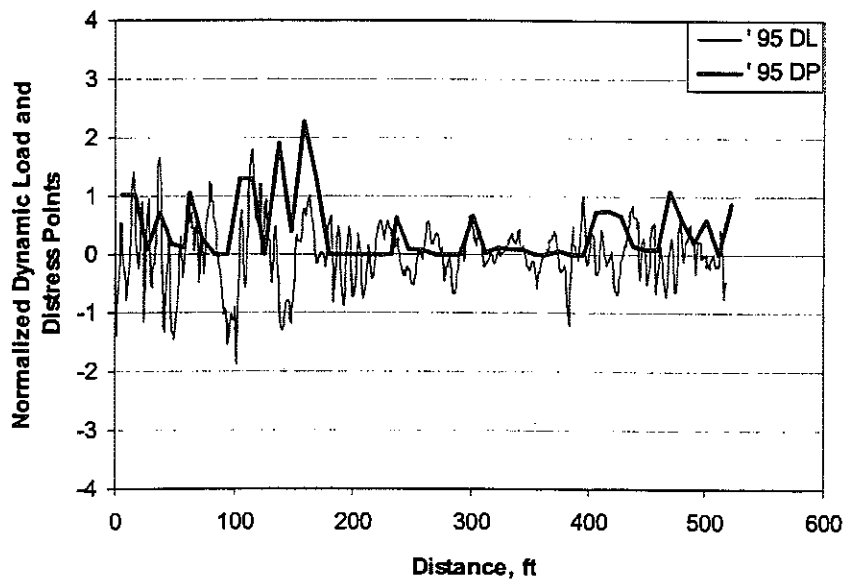


FIGURE 3.16 **Normalized Dynamic Load and Distress Points versus Longitudinal Distance along Subsection #3 (MP 5.3 to 5.4) of EB I-94 Project (CS 38101)**

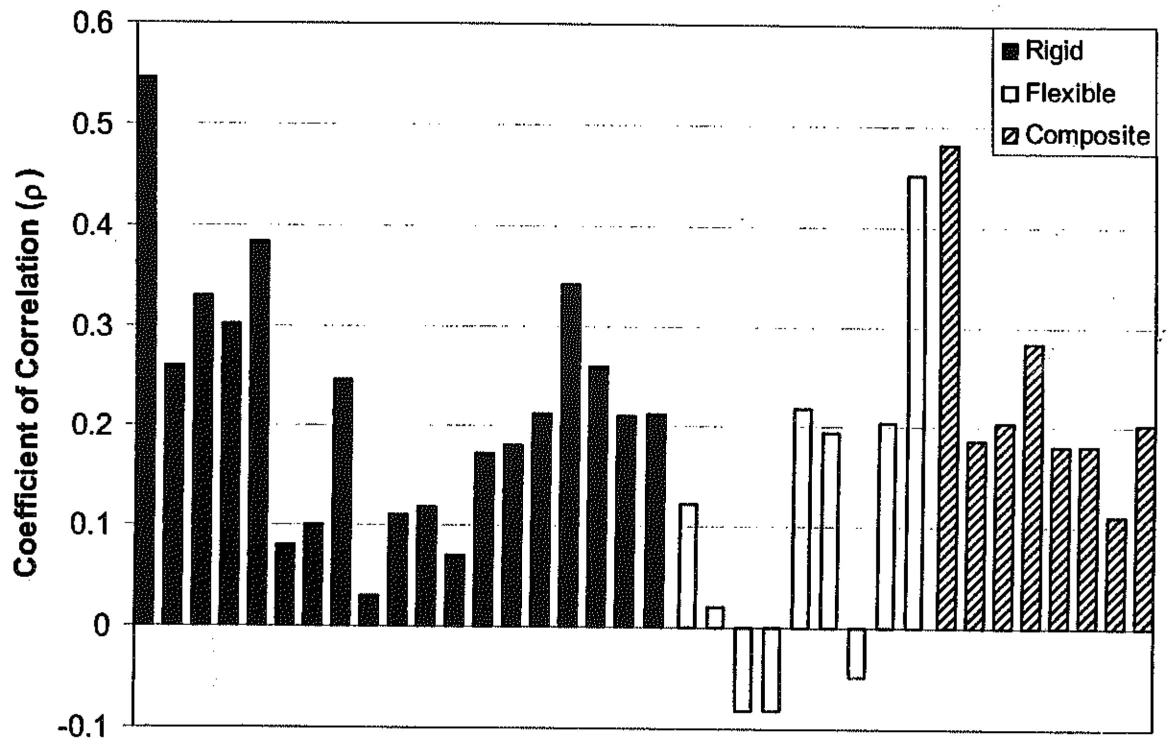


FIGURE 3.17 Coefficient of Correlation (ρ) between Axle Load and Distress Points for All Subsections Analyzed

3.4.6.1 Example Site 1 - EB I-94 (CS 11017, MP 1.0 - 5.8)

The CS 11017 section is a plain concrete pavement with an open-graded base course. Prior to its reconstruction in 1995, the overall level of RQI values for the previous pavement was very high. However, the DI showed severe variability along the project, as shown in Figure 3.5 (a) and (b). Three subsections that show matching RQI and DI peaks were selected for further analysis. Figure 3.9 shows the year-to-year trend of RQI, IRI, DLC and DI from 1992 to 1997. These values are normalized with respect to threshold values of RQI = 70, IRI = 150, DLC = 12%, and DI = 40. The figure shows that RQI and IRI levels are at or above the threshold value for rough pavements; consequently, the DLC values are also high. This high roughness level apparently caused the DI to increase from about 70% of its threshold value to about 100% in 1995. This prompted the rehabilitation action in 1995. Figure 3.13 plots the dynamic loading component and distress points normalized to their respective 95th percentile values (entire population analyzed) for the first subsection (MP 2.6 to 2.7). The figure shows a very good match between the two curves. The ρ-value for the correlation between DL and DP distributions is 0.547, which is the highest value among all subsections. The ρ-values for Subsections 2 and 3 have ρ-values of 0.261 and 0.331, respectively. The results show that a very good match between the distress and load curves could be obtained in spite of the low ρ-values. It can be assumed that the distress accumulation for the three subsections selected in this case is mainly load-related.

Subsequent discussion with the MDOT Technical Advisory Group overseeing the project revealed that the pavement exhibited numerous transverse cracks that may have been initiated as hairline cracks during initial construction, and have propagated under the load action. Some minor faulting had developed and some major spalling had taken place, mainly due to load action. These findings, namely that the cracks have deteriorated due to load action, support the conclusion made based on the PMS data.

3.4.6.2 Example Site 2 - NB I-69 (CS 23063, MP 0.0 -5.0)

The CS 23063 section is a jointed reinforced concrete pavement with 27 ft. panels and an open-graded base course. The pavement was constructed in 1991. This section had low DI and RQI levels prior to 1997. In 1997, the DI increased significantly in the section from MP 3.2 to MP 4.5, while there was no big increase in RQI (see Figure 3.6 (b) and (c)). This increase in DI cannot be explained by roughness or dynamic loading. Three subsections that show high DI peaks were selected for further analysis. Figure 3.10 shows the year-to-year trend of RQI, IRI, DLC and DI from 1992 to 1997 for the three subsections. These values are normalized with respect to threshold values of RQI = 70, IRI = 150, DLC = 12%, and DI = 40. The figure shows that RQI and IRI levels are significantly below the threshold value for rough pavements; consequently, the DLC values are relatively low. For Subsections 2 and 3 (Figure 3.6 (a) and (b)), some portions of these sections had a great increase in DI in 1997 while there was no big increase in roughness. In Subsection 4, RQI is at a somewhat higher level, and DI significantly increased in 1997, as shown in Figure 3.6 (c). Figure 3.10 plots the dynamic loading component and distress points normalized to their respective 95th percentile values (entire population analyzed) for the first subsection (MP 3.2 to 3.3). The figure shows a very poor match between the two curves. The ρ-value for the correlation between DL and DP distributions for this subsection is 0.031. It is clear that the distress point (DP) accumulation is not related to dynamic loading (DL). The ρ-values for Subsections 2 and 3 have ρ-values of 0.111 and 0.119, respectively. The results show a very poor match between the distress and load curves. It can therefore be assumed that the distress accumulation for the three subsections selected in this case is not primarily load-related.

Subsequent discussion with the MDOT Technical Advisory Group overseeing the project revealed that the pavement exhibited one to two transverse cracks per panel, which are thought to have been initiated as shrinkage cracks during initial construction (the records show the air temperature during construction equal to 86 ° F (30° C)). However, these cracks have remained tight and exhibited excellent load transfer. A limestone aggregate was used in the concrete mix. These findings, namely that the cracks are not necessarily related to roughness and dynamic loading, support the conclusion which was made based on the PMS data.

3.4.6.3 Example Site 3 - EB US-10 (CS 09101, MP 0.9-7.3)

The CS 09101 section was reconstructed in 1990 by rubblizing the old concrete slabs and overlaying them with an asphalt concrete layer. This section shows a dramatic increase in DI-values from 1993 to 1995, particularly in the subsections from MP 1.6 to MP 5.1 (see Figure 3.7 (b)). DI-values were further amplified in 1997 for some subsections, while they were reduced for other subsections (Figure 3.7 (c)) presumably as a result of maintenance activities. The RQI level remained relatively low throughout the period from 1992 to 1996, although slight increases are seen from 1993 to 1995 and from 1995 to 1997. The increase in DI cannot be explained by roughness or dynamic loading. Three subsections that show high DI peaks were selected for further analysis. Figure 3.11 shows the year-to-year trend of RQI, IRI, DLC and DI from 1992 to 1997 for the three subsections. These values are normalized with respect to threshold values of RQI = 70, IRI = 150, DLC = 12%, and DI = 40. The figure shows that RQI and IRI levels are significantly below the threshold value for rough pavements; consequently, the DLC values are relatively low, although there is some increase in DLC-values for Subsection 3. In all subsections, (Figure 3.11 (a) through (c)), DI-values greatly increased from 1993 to 1995, exceeding the threshold value of 40. In Subsection 1, the DI further increased in 1997 to reach 1.7 times the threshold value. Subsections 2 and 3, on the other hand, show a relative decrease in DI, presumably as a result of some maintenance activity. Figure 3.15 plots the dynamic loading component and distress points normalized to their respective 95^{th} percentile values (entire population analyzed) for the second subsection (MP 3.1 to 3.2). The figure shows a very poor match between the two curves. The ρ-value for the correlation between DL and DP distributions for this subsection is - 0.081. It is clear that the distress point (DP) accumulation is not related to dynamic loading (DL). Subsections 1 and 3 have ρ-values of 0.122 and -0.081, respectively. The results show a very poor match between the distress and load curves. It can therefore be assumed that the distress accumulation for the three subsections selected in this case is not primarily load-related.

Subsequent discussion with the MDOT Technical Advisory Group overseeing the project revealed that the pavement exhibited longitudinal cracks both inside and outside the wheel path as well as some transverse cracks, which are thought to be material-related (the AC mix is low in asphalt content and has high air voids in the leveling course). Some full-depth patch repair was performed in 1996. These cracks are considered premature by MDOT, and their cause is being investigated in an on-going research project funded by MDOT. These findings, namely that the cracks are not necessarily related to roughness and dynamic loading, support the conclusion which was made based on the PMS data.

3.4.6.4 Example Site 4 - EB I-94 (CS 38101 , MP 0.0 - 8.7)

The CS 38101 section is a composite pavement with 99-ft reinforced concrete slabs that were overlaid by a 4 in. asphalt concrete layer in 1985. Figures 3.8 (a), (b) and (c) show the RQI and DI profiles along the entire project length for 1993, 1995 and 1997, respectively. The profiles are normalized with respect to the threshold value of RQI = 70 and DI = 40, respectively. The match between RQI and DI profiles from year to year is excellent. The levels of RQI and DI values are intermediate to high in some subsections. Three subsections that show high RQI and DI peaks were selected for further analysis. Figure 3.12 shows the year-to-year trend of RQI, IRI, DLC and DI from 1992 to 1997. These values are normalized with respect to threshold values of RQI = 70, IRI = 150, DLC = 12%, and DI = 40. The figure shows that RQI and IRI levels are at or above the threshold value for rough pavements; consequently, the DLC values are also high. This apparently caused the DI to increase from about 70% of its threshold value to about 100 to 120 % in 1997. Figure 3.16 plots the dynamic loading component and distress points normalized to their respective 95th percentile values (entire population analyzed) for the third subsection (MP 5.3 to 5.4). The figure shows a very good match between the two curves. The ρ-value for the correlation between DL and DP distributions is 0.284, which is a low value, considering the very good match observed. The ρ-values for Subsections 1 and 2 have ρ-values of 0.0.482 and 0.204, respectively. The results show that a very good match between the distress and load curves could be obtained in spite of the low ρ-values. It can be assumed that the distress accumulation for the three subsections selected in this case is mainly load-related.

Subsequent discussion with the MDOT Technical Advisory Group overseeing the project revealed that the pavement exhibited reflective cracking at all the joints, and that a deterioration of the cracks due to load action forced a major maintenance action (milling and overlay) in 1998. These findings, namely that the reflective cracks have deteriorated due to load action, support the conclusion made based on the PMS data.

CHAPTER 4
NETWORK-LEVEL RELATIONSHIPS BETWEEN RIDE QUALITY AND DISTRESS INDICES

Summary

To verify the existence of a roughness threshold at which distress accumulation starts to accelerate, relationships between distress and roughness were obtained using DI and RQI data from MDOT's PMS database. Three data sets, totaling 97 pavement projects, were selected for this analysis. An attempt was made to isolate dynamic-load-related distresses from other distresses. Using the three data sets, distress types that are dominant in relatively rough pavements and in relatively smooth pavements were determined for different distress (DI) levels. The results of this analysis from the first data set showed that for all three types of pavements, transverse cracking with associated distress was dominant in relatively rough pavements. Transverse joint deterioration, delamination and patch deterioration were also found to be dominant in relatively rough rigid pavements. However, the results from the second and third data sets did not agree with those from the first data set. These results showed that for rigid pavements, unlike the results from the first data set, transverse cracking with associated distress was dominant in relatively smooth sections at high DI level, and transverse joint deterioration was dominant in relatively smooth sections at low DI level. For composite pavements, there was no major difference in proportions of transverse crack with associated distress between rough and smooth sections at high DI level. For flexible pavements, transverse cracking with associated distress was dominant in smooth sections, and longitudinal distress was dominant in rough sections at high DI level. Therefore, it was concluded that dynamic load-related distress types could not be decided upon from this analysis.

Using the three data sets, DI-RQI relationships were obtained. Rigid pavements had the highest R^2-values: $R^2 = 0.488$, 0.699 and 0.731 for the first, second and third data sets, respectively. Flexible pavements had the lowest R^2-values (0.311, 0.448 and 0.507), and composite pavements had R^2-values in-between. From these relationships, critical RQI values where the second derivative of the DI-RQI function is maximal were obtained. The three data sets gave critical RQI-values of 57, 54 and 57 for rigid pavements, and 44, 48 and 42 for composite pavements. For Flexible pavements, critical RQI-values were found to be 45, 40 and 44; however, these values are not reliable because of the high scatter in the data. This large variability came from the fact that distress is caused not only by truck loading but also by many other factors. These critical values represent the overall behavior of pavements at the network level, and may not be applicable for a particular pavement project. Therefore, such values can be used for network-level pavement management, and not necessarily at the project level.

4.1 INTRODUCTION

All road surfaces have some level of roughness even when they are new, and they become increasingly rougher with age depending on pavement type, traffic volume, environment etc. An increase in pavement roughness leads to higher dynamic axle loads in certain portions of the road. This amplification in the load magnitude can lead to a tangible acceleration in pavement distress; the increased distress, in turn, makes the pavement surface rougher. This process is the result of the interaction between vehicles and pavements. The relationship between pavement damage and roughness (due to truck-pavement interaction) can be used to give an early warning to the pavement management agency under the following hypothesis: that there is a critical value of roughness at which a sharp increase in dynamic load occurs, which would lead to an acceleration in pavement damage.

In this chapter, the relationship between the distress index (DI) and the roughness index (RQI) is sought using measured distress and roughness data for 97 projects that have different ages and different levels of distress and roughness. RQI-DI relationships were generated for the three pavement types. The existence of critical roughness values where a sharp increase in distress occurs was confirmed at the network level using these relationships.

4.2 SITE SELECTION

Three independent data sets (for a total of 97 projects) were selected from the Michigan pavement network. The first data set has thirty-seven pavement projects: Ten projects with known performance records and having exhibited some distress, and twenty-seven projects where preventive maintenance activities were done during 1997 and 1998. Thirteen of the thirty-seven sites were rigid; fifteen were flexible; and nine were composite pavements. The second and third data sets were selected randomly from the Michigan pavement network. Each data set has thirty projects: ten rigid, ten composite and ten flexible pavements. These selected projects cover a wide range in pavement age and traffic volume. The length of these pavement projects varies from 1.5 to 23 miles with an average project length of 7.4 miles. Their ages range from 1 to 39 years. The commercial daily traffic volume ranges from 70 to 12300. The distribution of these projects in traffic volume and pavement age is shown in Figure 4.1. This figure shows that, as expected, rigid pavements have higher traffic volumes than flexible and composite pavements. This is because most of interstate and US highways are rigid pavements. The age for selected rigid pavements is as high as 39 years; while composite and flexible pavements have ages less than 25 years. The selected sites for each phase are listed in Tables 4.1, 4.2 and 4.3 and are shown in Figures 4.2, 4.3 and 4.4.

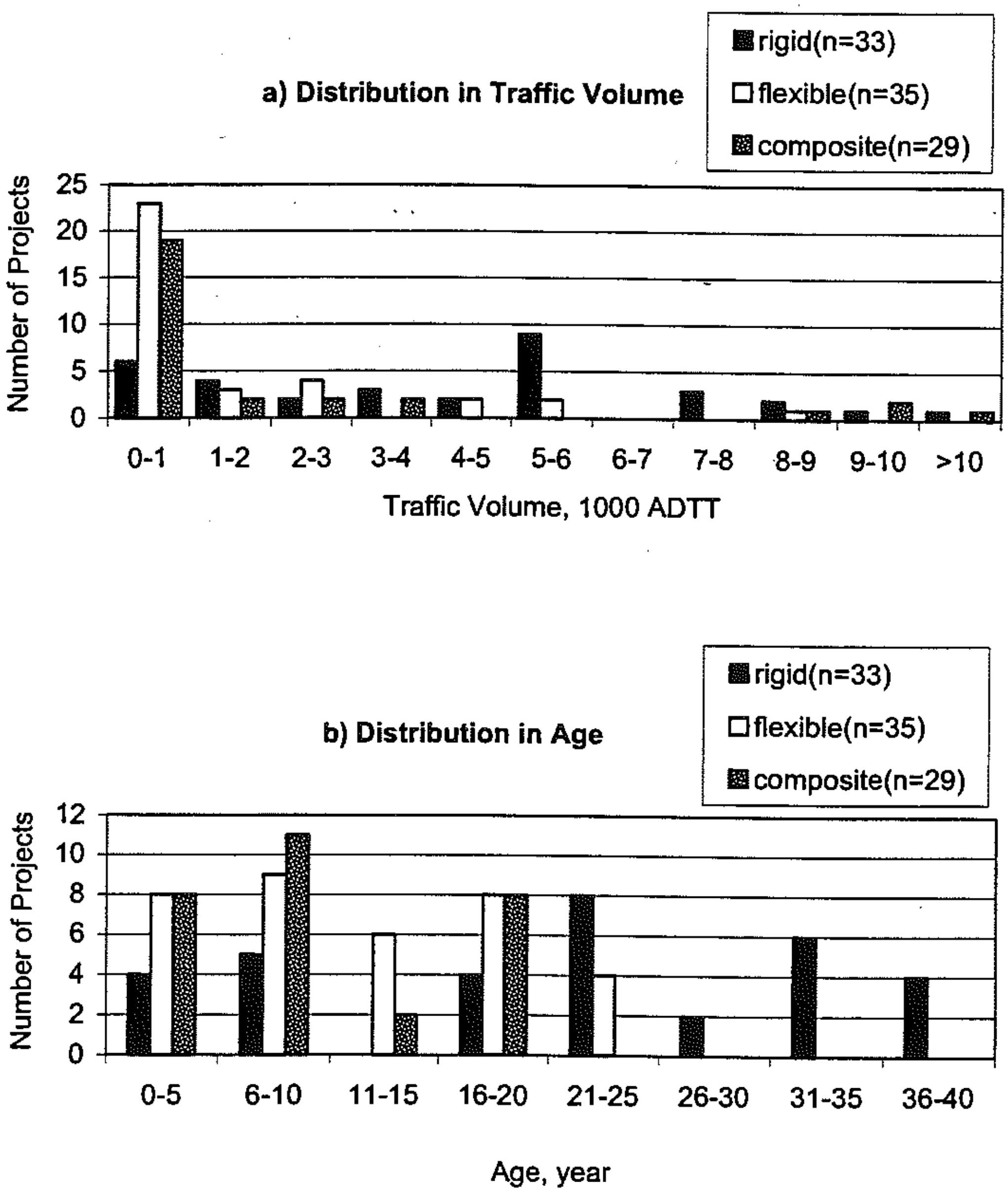


FIGURE 4.1 Distribution of Projects in Traffic Volume and Pavement Age

TABLE 4.1 List of the First Data Set

Pavement Type	No.	Route	Control Section	Mile Post	Length (mile)	Commercial Traffic Volume (1997)	Const. Year
Rigid Pavements	1	EB I-94	11017	1.0-5.9	4.9	7700	1959
	2	EB US-10	18024	0.0-7.6	7.6	1100	1976
	3	WB US-10	18024	0.0-7.6	7.6	1100	1976
	4	NB I-69	23063	0.0-5.0	5.0	4000	1991
	5	EB I-69	76024	0.0-3.8	3.8	5600	1991
	6	WB US-2	21022	3.0-5.6	2.6	940	1957
	7	WB US-2	21022	5.6-8.4	2.8	940	1962
	8	EB US-2	21022	6.3-8.4	1.9	940	1962
	9	WB US-2	21025	0.0-6.2	6.2	1000	1971
	10	EB US-2	21025	0.0-6.2	6.2	1000	1971
	11	NB US-24	63031	0.0-2.5	2.5	1000	1953
	12	NB US-31	70014	0.0-5.5	5.5	2300	1954
	13	WB I-196	70023	0.0-5.5	5.5	4400	1956
Total					62.1		
Flexible Pavements	1	EB US-10	09101*	0.9-7.4	6.5	2400	1990
	2	EB I-96	33084*	9.0-17.5	8.5	5900	1993
	3	NB US-23	47014*	0.0-7.2	7.2	5600	1992
	4	M-88	05031	19.3-20.8	1.5	510	1978
	5	M-95	22013	0.0-13.0	13.0	330	1982
	6	M-57	25102	0.0-5.8	5.8	680	1975
	7	M-57	25102	5.8-9.9	4.1	680	1978
	8	M-30	26032	0.0-16.6	16.6	150	1984
	9	M-57	29022	0.0-9.8	9.8	510	1984
	10	M-28	31021	0.0-9.2	9.2	120	1984
	11	M-65	35012	7.0-16.0	9.0	280	1973
	12	M-36	47041	13.4-20.6	7.2	70	1971
	13	M-36	47041	20.6-23.2	2.6	70	1986
	14	NB US-31	61074	0.0-3.1	3.1	2200	1978
	15	NB US-27	72014	0.0-8.9	8.9	840	1975
Total					113.0		

TABLE 4.1 List of the First Data Set (Continued)

Pavement Type	No.	Route	Control Section	Mile Post	Length (mile)	Commercial Traffic Volume (1997)	Const. Year
Composite Pavements	1	EB I-94	38101	0.0-8.7	8.7	8900	1985
	2	NB US-127	38131	0.0-5.2	5.2	1300	1987
	3	US-12	11011	0.0-3.2	3.2	760	1989
	4	M-115	18011	0.0-12.2	12.2	660	1985
	5	WB US-2	21022	0.0-2.0	2.0	940	1991
	6	M-95	22012	10.2-16.2	6.0	290	1987
	7	M-52	76012	2.3-9.2	6.9	470	1987
	8	M-21	76062	3.3-12.6	9.3	530	1987
	9	SB US-131	78012	0.1-2.5	2.4	1400	1990
Total					55.9		

TABLE 4.2 List of the Second Data Set

Pavement Type	No.	Route	Control Section	Mile Post	Length (mile)	Commercial Traffic Volume (1997)	Const. Year
Rigid Pavements	1	NB I-69	12034	0.0-9.4	9.4	5600	67
	2	SB I-69	23061	0.0-9.5	9.5	5100	72
	3	WB I-69	25084	0.0-11.7	11.7	5800	71
	4	EB I-69	44044	0.0-17.6	17.6	4200	84
	5	NB I-75	06111	0.0-17.0	17.0	1900	68
	6	NB I-75	58152	0.0-5.0	5.0	8000	90
	7	EB I-94	50112	0.0-6.1	6.1	3200	63
	8	EB I-94	80024	5.1-10.5	5.4	9100	87
	9	WB I-96	82122	2.0-12.0	10.0	8500	77
	10	NB US-131	39014	0.0-4.2	4.2	3600	63
Total					95.9		
Flexible Pavements	1	EB I-94	11015	0.0-19.3	19.3	8700	89
	2	NB I-196	80012	0.0-9.0	9.0	4600	77
	3	EB US-12	14041	9.1-16.0	6.9	500	70
	4	NB US-31	61074	0.0-3.7	3.7	2200	78
	5	SB US-131	54014	0.0-16.1	16.1	1500	84
	6	M-20	54021	1.9-4.1	2.2	1100	84
	7	M-30	56032	0.0-9.1	9.1	150	88
	8	M-35	21032	10.3-25.7	15.4	150	76
	9	M-43	80042	6.2-10.5	4.3	310	94
	10	M-50	08081	0.0-2.8	2.8	700	71
Total					88.8		
Composite Pavements	1	NB I-75	63173	0.0-14.4	14.4	3100	84
	2	NB I-75	86000	0.0-4.3	4.3	790	92
	3	NB I-75BL	63091	0.0-3.6	3.6	2600	74
	4	EB I-94	81104	0.0-6.5	6.5	9900	86
	5	WB US-2	49022	0.0-12.4	12.4	580	84
	6	WB US-10	53022	0.0-9.4	9.4	520	81
	7	US-23	06072	0.0-9.5	9.5	770	77
	8	US-41	55011	3.2-21.4	18.2	420	91
	9	M-18	26011	0.0-5.2	5.2	230	77
	10	M-50	58032	0.0-5.9	5.9	560	77
Total					89.4		

TABLE 4.3 List of the Third Data Set

Pavement Type	No.	Route	Control Section	Mile Post	Length (mile)	Commercial Traffic Volume (1997)	Const. Year
Rigid Pavements	1	SB I-69	23061	9.5-13.4	3.9	5100	61
	2	EB I-69	25085	0.0-2.9	2.9	5800	70
	3	EB I-69	44043	0.0-7.2	7.2	5400	71
	4	NB I-75	09035	0.0-23.0	23.0	2700	68
	5	WB I-94	39022	4.3-11.5	7.2	12300	85
	6	EB I-94	80023	3.7-13.4	9.7	8900	84
	7	EB I-96	34043	0.0-7.1	7.1	5300	87
	8	EB I-96	47065	0.0-5.5	5.5	5900	92
	9	NB US-23	81076	0.0-6.6	6.6	7500	62
	10	NB US-131	59012	0.0-9.8	9.8	1900	73
Total					82.9		
Flexible Pavements	1	NB I-196	11111	0.0-7.9	7.9	4800	75
	2	NB US-27	20016	0.0-6.3	6.3	840	77
	3	NB US-31	53034	0.0-11.0	11.0	410	89
	4	NB US-31	70016	0.0-2.9	2.9	2300	78
	5	NB US-131	67016	0.0-5.6	5.6	1500	86
	6	M-13	73051	15.5-18.4	2.9	560	70
	7	M-28	66021	0.0-8.5	8.5	330	84
	8	M-43	80042	0.0-6.2	6.2	310	73
	9	M-52	33091	2.1-6.6	4.5	370	84
	10	M-52	81013	0.0-5.2	5.2	350	94
Total					61.0		
Composite Pavements	1	NB I-75	25131	0.0-8.7	8.7	3100	88
	2	NB I-75	73111	0.0-8.4	8.4	3000	90
	3	NB I-75	82194	0.0-2.4	2.4	12000	84
	4	EB I-94	39024	0.0-7.4	7.4	9400	93
	5	EB I-94BL	38083	3.0-5.8	2.8	800	77
	6	WB US-2	75022	0.0-13.8	13.8	670	82
	7	EB US-12	81063	0.0-3.6	3.6	560	74
	8	US-31	10031	0.0-6.3	6.3	360	77
	9	US-127	46011	0.0-5.1	5.1	430	76
	10	M-115	18011	0.0-13.2	13.2	660	85
Total					71.7		

FIGURE 4.2 Location of Rigid Pavement Projects

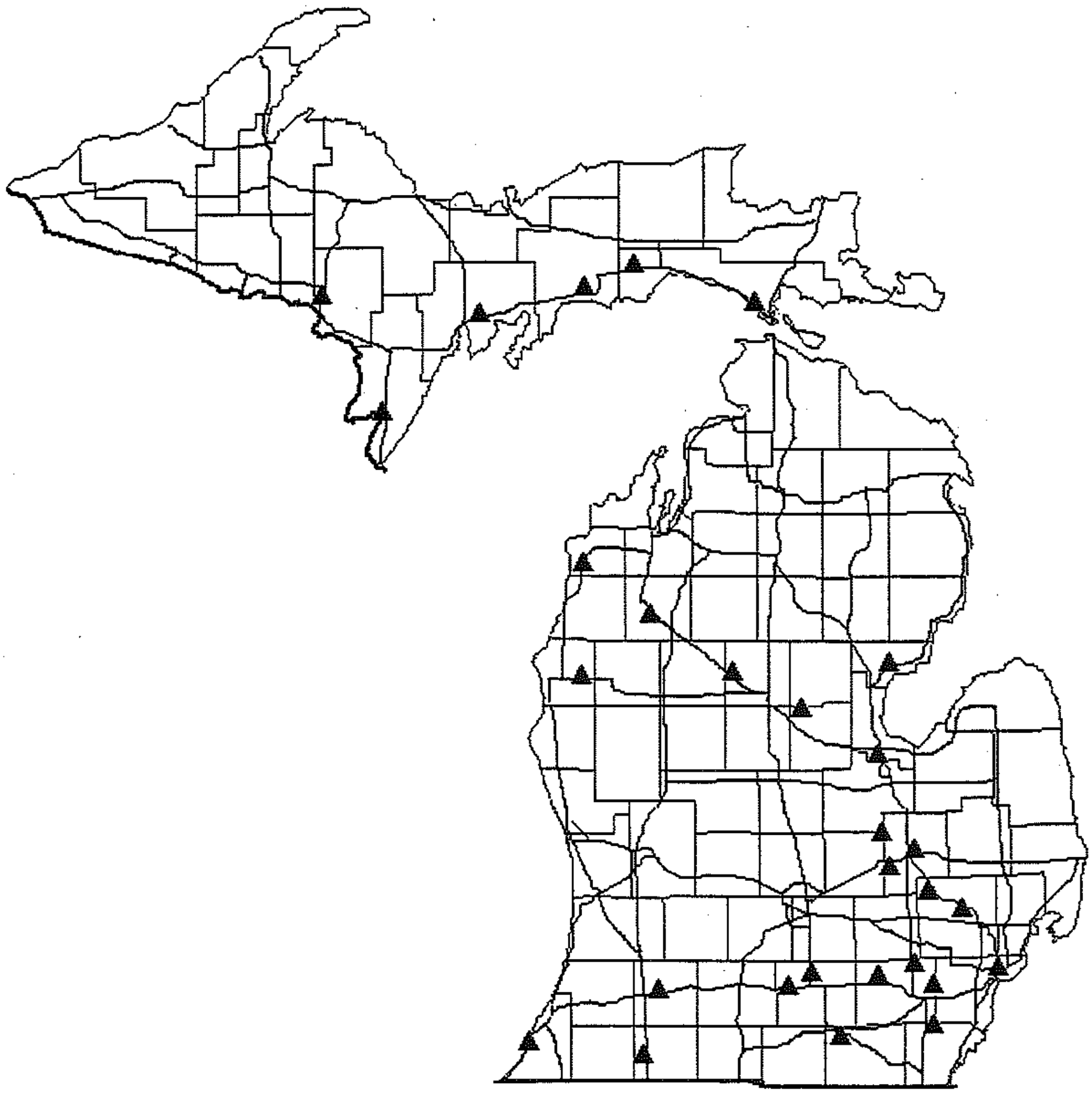


FIGURE 4.3 Location of Composite Pavement Projects

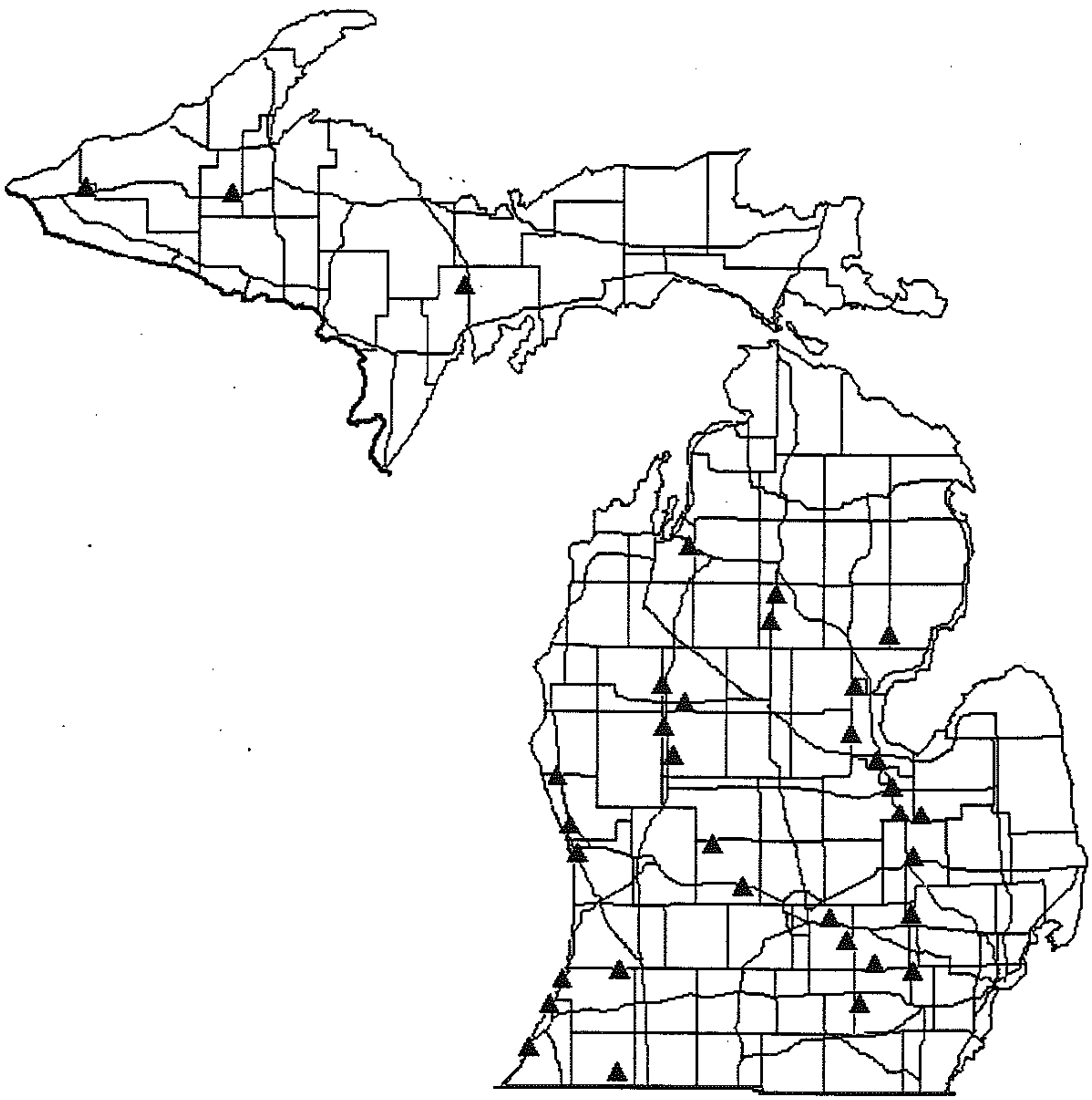


FIGURE 4.4 Location of Flexible Pavement Projects

4.3 DATA COLLECTION

For these selected sites, DI and RQI data as well as road surface profiles were obtained from the MDOT PMS database. DI values were available for 1993, 1995 and 1997; whereas RQI values and road profiles were available for the period between 1992 and 1996. The DI and RQI data were available for each 0.1-mile long section. Surface profile data were converted to ASCII files containing surface elevations at 3-in intervals. Detailed distress data in the form of distress type, severity and extent was also available at 10-ft intervals. The data were then converted to Distress Points (DP).

4.4 ANALYSIS ON LOAD-RELATED DISTRESS TYPES

Distress in pavements is caused not only by truck loads but also by many other factors such as material and environmental factors. For this reason, the relationship between distress and roughness is complex. If dynamic load-related distress types can be isolated from the other distress types, a better relationship between distress and roughness could be obtained. An attempt to isolate dynamic load-related distress types was made using the three independent data sets. For this analysis, several subsections having the same range in DI level, but different RQI levels were selected. For each selected subsection, distress points of each distress type were calculated. In this calculation, transverse and longitudinal cracks were divided into two types: i) cracks having no associated distress; and ii) cracks with associated distress such as spalling. Associated distress is a distress occurring around a main distress, and is used to define subsequent deterioration of the main distress in MDOT PMS.

Proportions of distress points of each distress type are plotted for relatively rough and relatively smooth subsections at each DI level (see Appendix A). The first data set showed that for rigid pavements, transverse cracks with associated distress, transverse joint deterioration, delamination and patch deterioration appear to be dominant in relatively rough sections at most DI levels while transverse cracks without associated distress are dominant in relatively smooth sections at most DI levels. For flexible and composite pavements, transverse cracks with associated distress appear to be dominant in relatively rough sections. For the first data set, it was possible to differentiate dynamic-load-related distress types from other distresses. However, further analysis conducted using the second and third independent data sets did not support this conclusion.

The second and third data sets showed that for rigid pavements, unlike the results from original data set, transverse cracks with associated distress are dominant in relatively smooth sections at high DI levels, while transverse joint deterioration is dominant in relatively smooth sections at low DI levels. For composite pavements, there is no major difference in proportions of transverse cracks with associated distress between rough and smooth sections at high DI levels. For flexible pavements, transverse cracks with associated distress are dominant in smooth sections and longitudinal cracks are dominant in rough sections at high DI levels. These results do not agree with those from the original data set. Therefore, it was concluded that dynamic load-related distress types could not be isolated. The detailed results of this analysis are in Appendix A.

4.5 RELATIONSHIP BETWEEN DI AND RQI

The DI-values for 0.5-mile sections were plotted against the corresponding RQI-values from three data sets for rigid, composite and flexible pavements as shown in Figures 4.5 to 4.16. The logistic model (7) having the following form was used for the regression analysis.

$$DI = a \times \frac{\exp(b + c \times RQI)}{1 + \exp(b + c \times RQI)} \tag{4.1}$$

where *a, b* and *c* are regression constants.

4.5.1 DI-RQI Relationship from the First Data Set

Regression analysis relating the DI to the RQI for the first data set resulted in R^2 values for rigid and composite pavements of 0.488 and 0.522, respectively. For flexible pavements, there is no good trend and the scatter in the data is very large, with an R^2-value of 0.311. This probably reflects the higher variability in flexible pavements, indicating that weak spots in the pavement will tend to "attract" damage as opposed to rougher spots inducing higher dynamic axle loads. The results of the regression analysis are summarized in Table 4.4.

TABLE 4.4 Regression Parameters and R^2-Values from the First Data Set

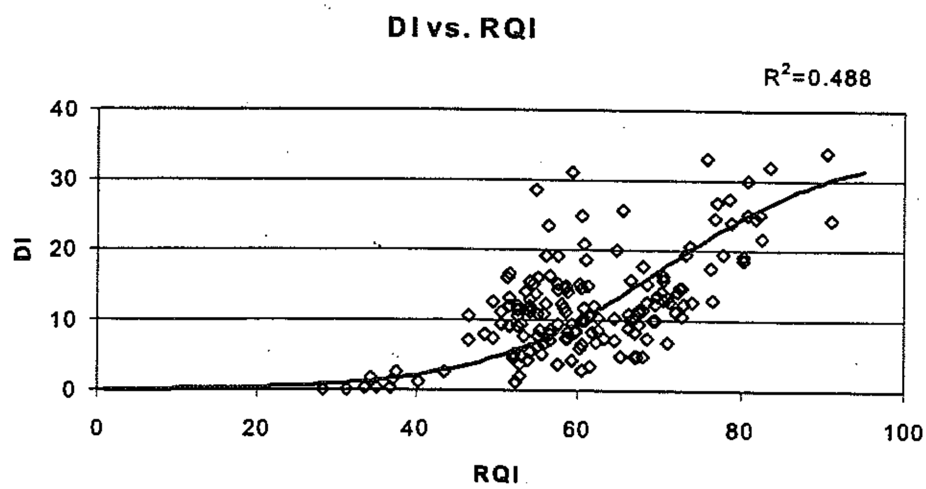
Pavement Type	a	b	c	R^2
Rigid Pavements	35	-6.325	0.090	0.488
Composite Pavements	90	-4.468	0.071	0.522
Flexible Pavements	100	-4.146	0.064	0.311

Relationships between RQI and DI show that the increased rate in distress is not constant, with the DI sharply increasing at a critical RQI level. This RQI value corresponds to the point at which the acceleration in pavement distress is maximal. Mathematically, it is where the second derivative of DI-RQI function is maximal. Acceleration in the accumulation of DI- vs. RQI-values for each pavement type is shown in Figures 4.5, 4.6 and 4.7. The RQI-value where the DI sharply increases was determined to be 57 for rigid pavements. This corresponds to an IRI of 1.70 m/km (106 in/mile). For composite pavements, this RQI-value was found to be 44. This corresponds to an IRI of 1.22 m/km (76 in/mile) for composite pavements. For flexible pavements, the corresponding RQI-value was found to be 45; however this value is not reliable because of the high scatter in the data.

It should be noted that these RQI-values represent the overall behavior of the pavement network, and therefore cannot be applied to a particular project. In other words, they are useful only for planning at the network level and not at the project level. It is also interesting to note that the critical RQI-value for rigid pavements corresponds to a DI of 8, as opposed to a DI of 18 and 22 for composite and flexible pavements, respectively. This may imply that the optimal time window for preventive maintenance actions corresponds to a lower distress level (higher remaining service life) for rigid pavements than for composite or flexible pavements.

4.5.2 DI-RQI Relationship from the Second and Third Data Sets

For each pavement type, the DI-values for 0.5-mile sections were again plotted against the corresponding RQI-values using the data from the second and third independent data sets (see Figures 4.8 to 4.13). The same logistic model that was used for the first data set was used in the regression analysis for these data sets. For rigid pavements, plots of DI against RQI from the new data sets have R^2-values of 0.699 and 0.731. For composite pavements, the R^2-values from the new data sets are 0.511 and 0.603. For flexible pavements, the R^2-values from the new data sets are 0.448 and 0.507. The results of the regression analysis are summarized in Tables 4.5 and 4.6. Again, the critical RQI-values were determined as the RQI-values where the acceleration in pavement distress (DI) is maximal. The critical RQI-values from the new data sets were determined to be 54 and 57 for rigid pavements. These values agree very well with that from the first data set that (RQI=57). For composite pavements, the critical RQI-values were determined to be 48 and 42. For flexible pavements, they were 40 and 44. These values agree reasonably well with the values obtained from the first data sets, which are 44 and 45 for composite and flexible pavements, respectively. The critical RQI-values were also determined using all data sets including the original data set and the two independent data sets (see Figures 4.14, 4.15 and 4.16). Using all data sets, the critical RQI-values were determined to be 55, 45 and 41 for rigid, composite and flexible pavements, respectively. The results of the regression analysis are shown in Table 4.7. Finally, the critical RQI-values determined from the original data set, two independent data sets and all data sets are summarized in Table 4.8.



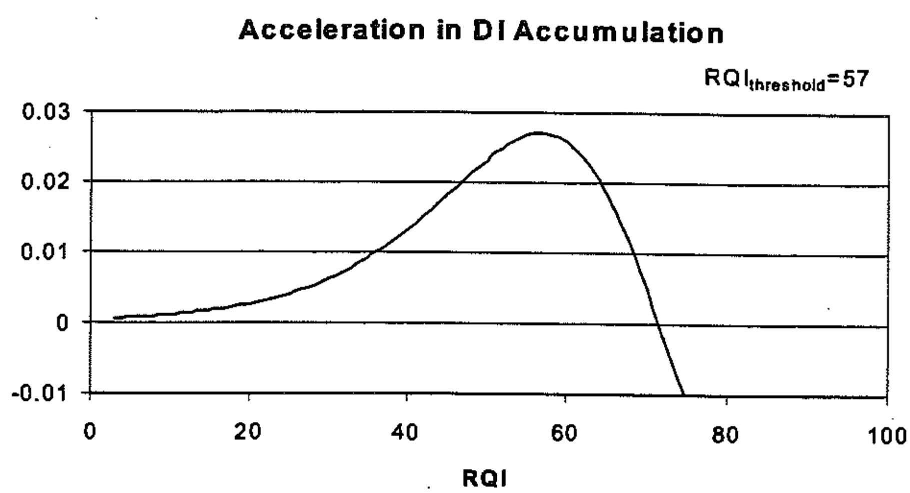
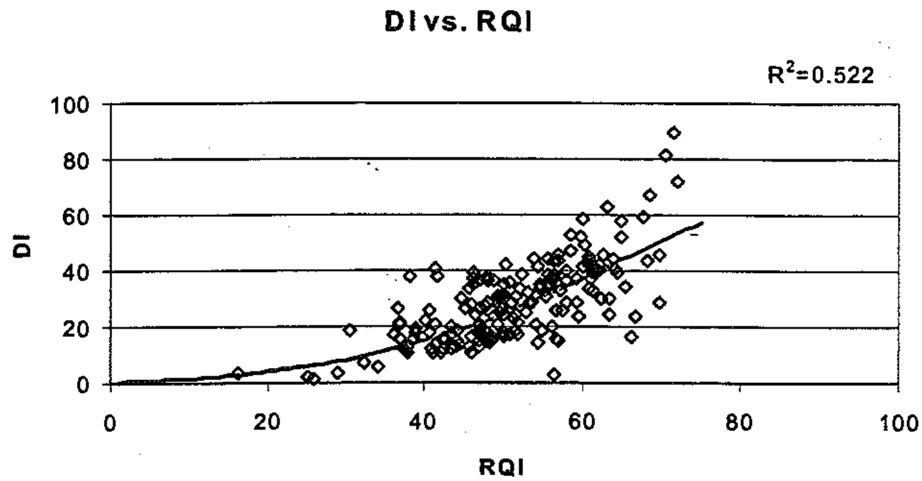


FIGURE 4.5 Relationship Between DI and RQI for Rigid Pavements from Data Set #1



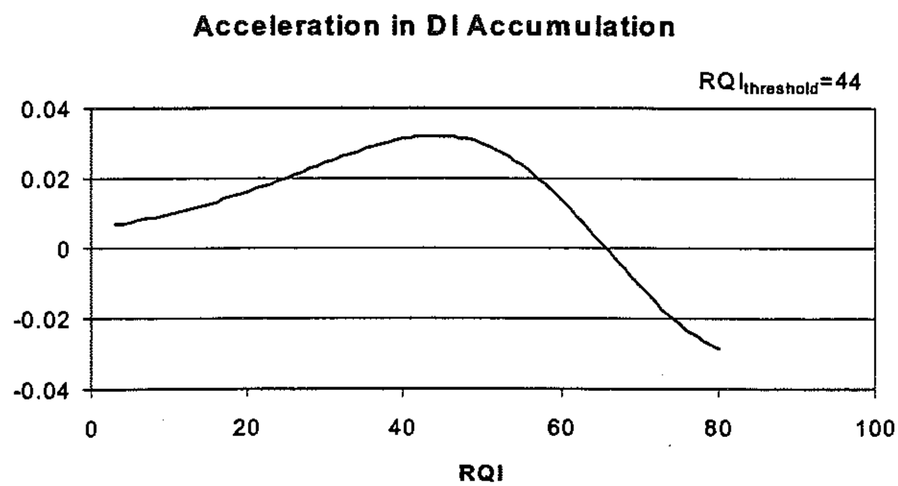


FIGURE 4.6 Relationship Between DI and RQI for Composite Pavements from Data Set #1

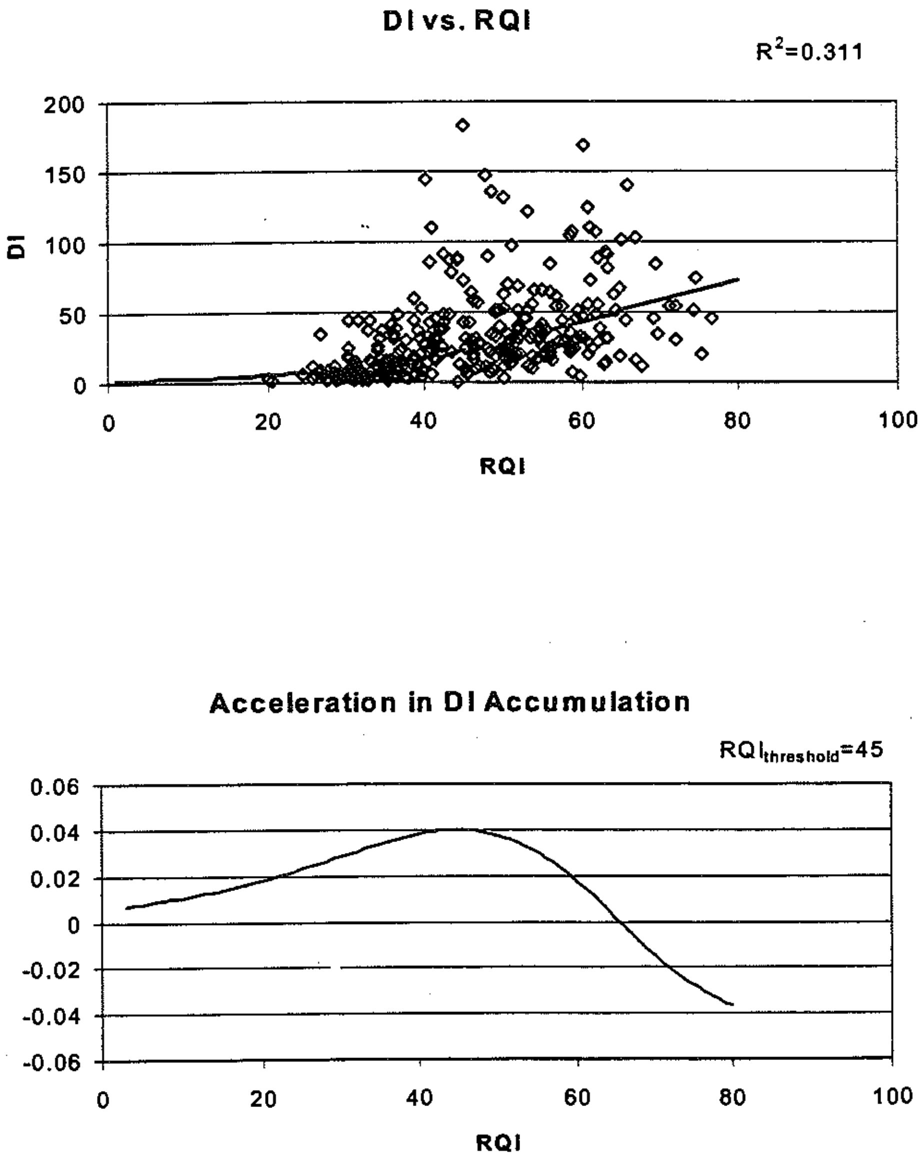
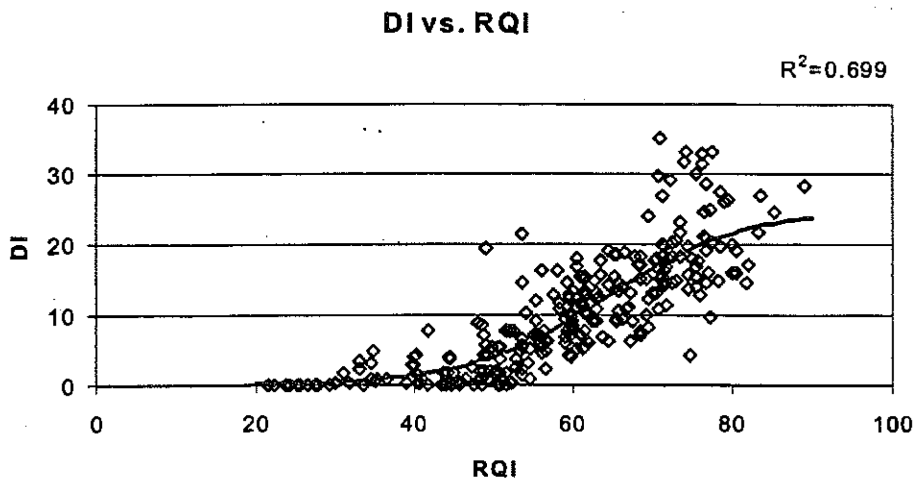


FIGURE 4.7 Relationship Between DI and RQI for Flexible Pavements from Data Set #1



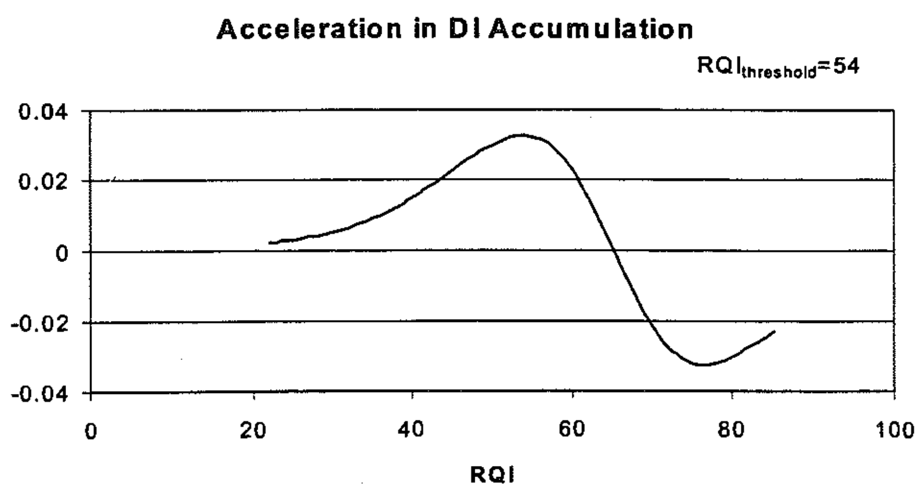


FIGURE 4.8 Relationship Between DI and RQI for Rigid Pavements from Data Set #2

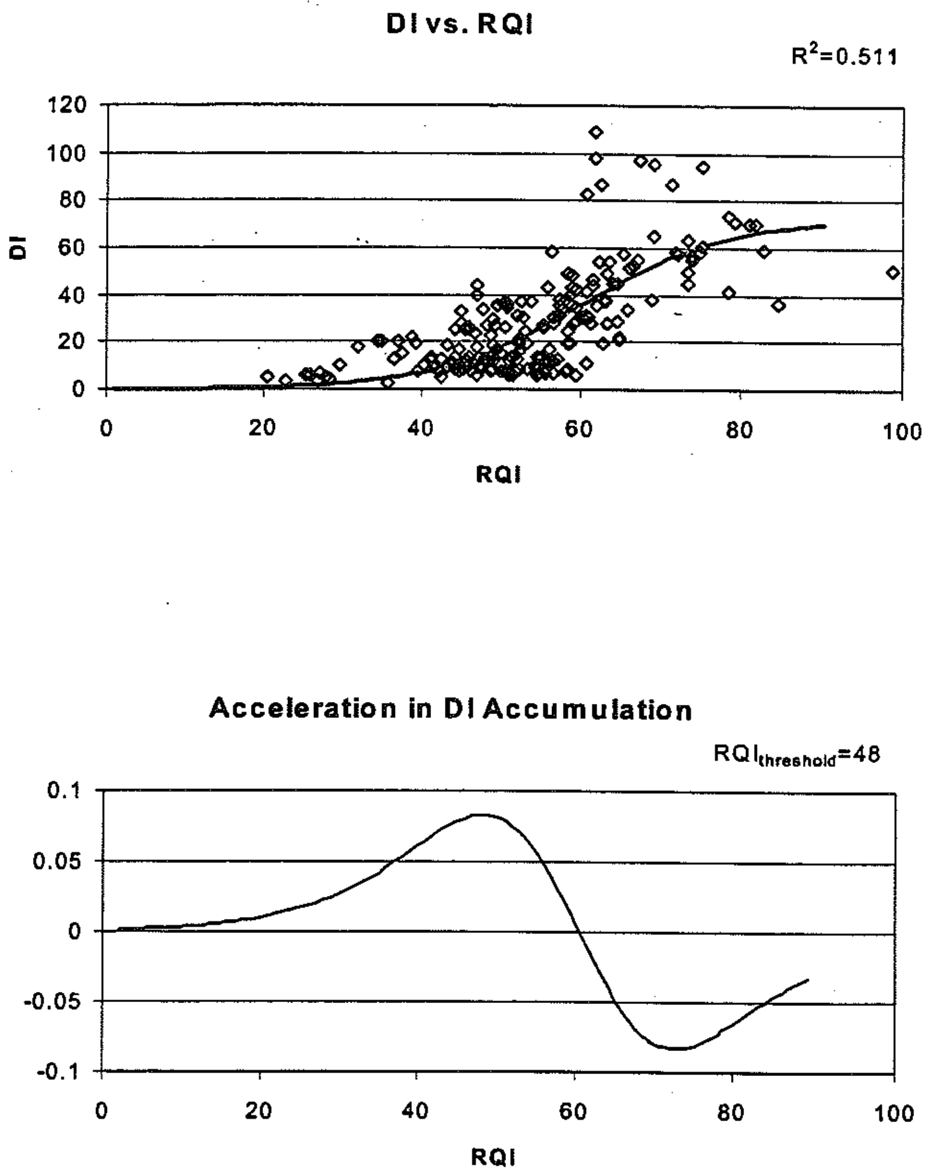
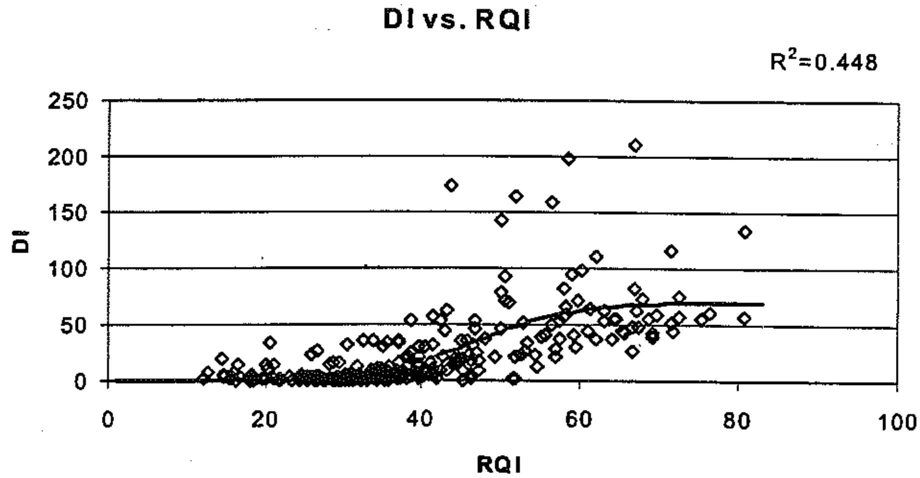


FIGURE 4.9 Relationship Between DI and RQI for Composite Pavements from Data Set #2



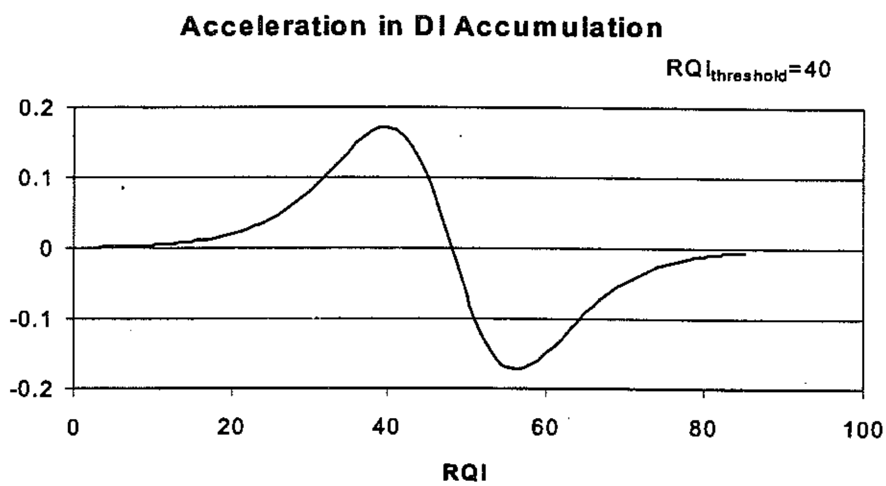
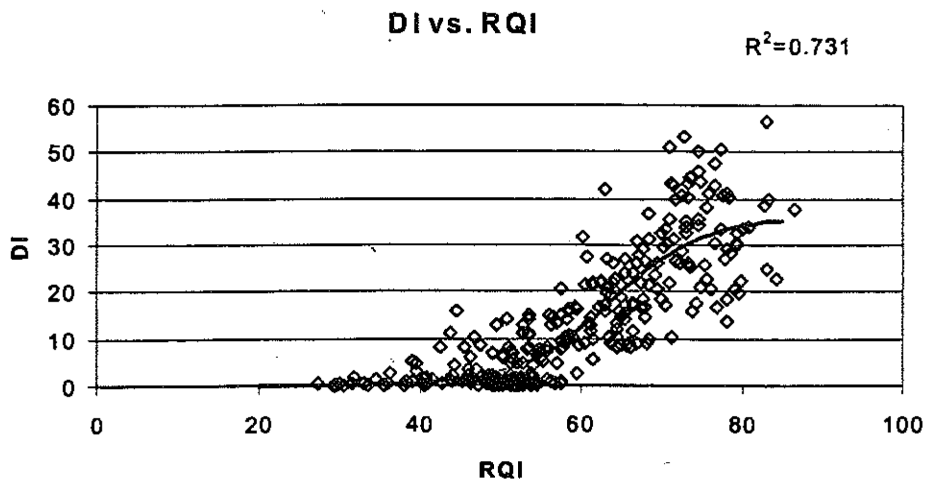


FIGURE 4.10 Relationship Between DI and RQI for Flexible Pavements from Data Set #2



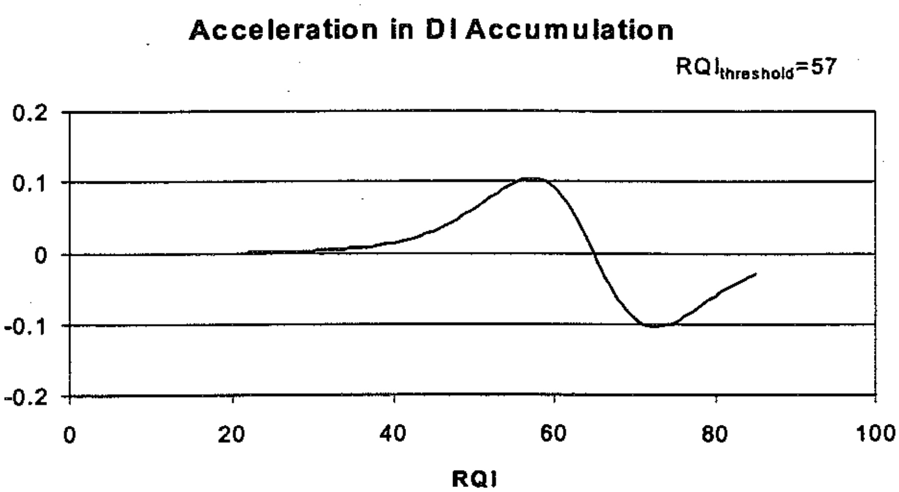
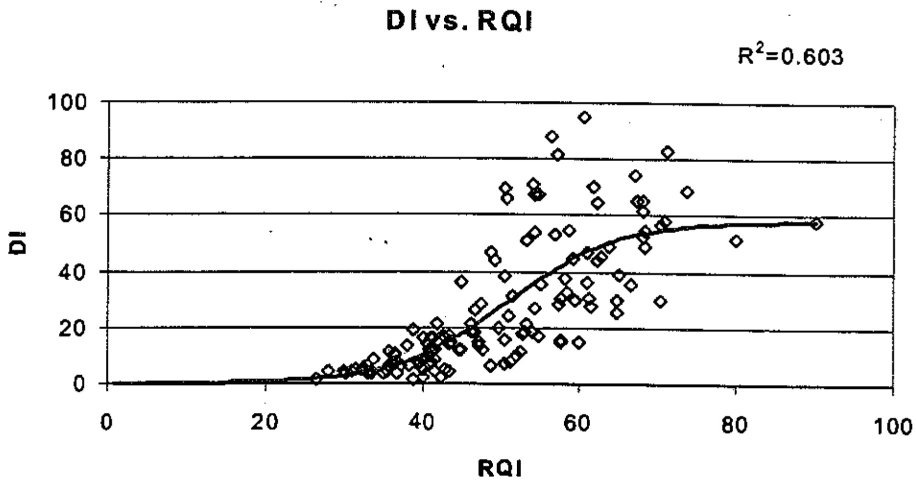


FIGURE 4.11 Relationship Between DI and RQI for Rigid Pavements from Data Set #3



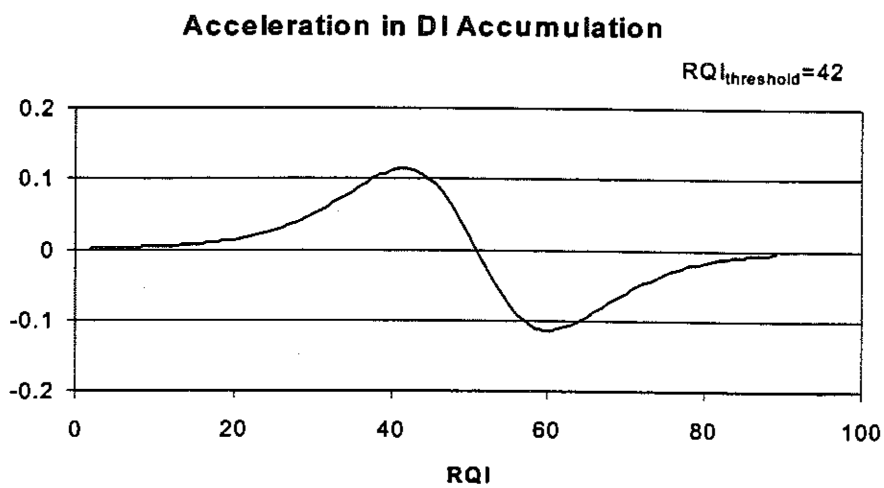
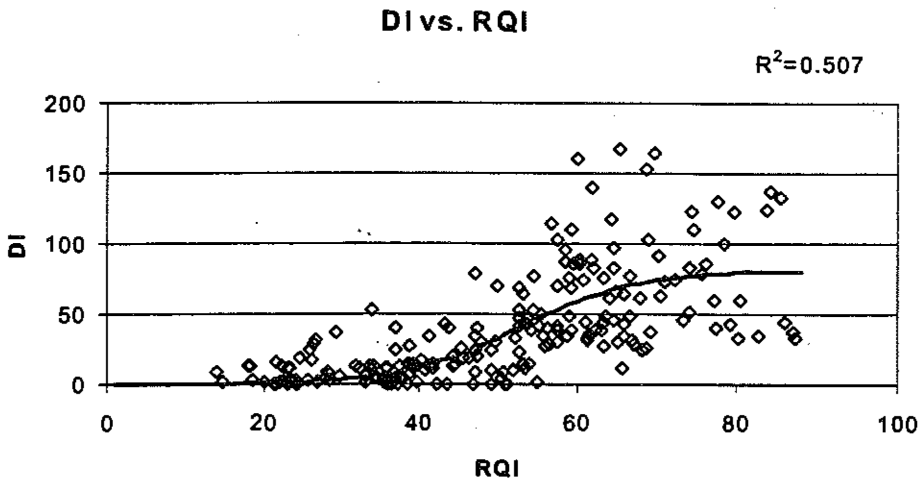


FIGURE 4.12 Relationship Between DI and RQI for Composite Pavements from Data Set #3



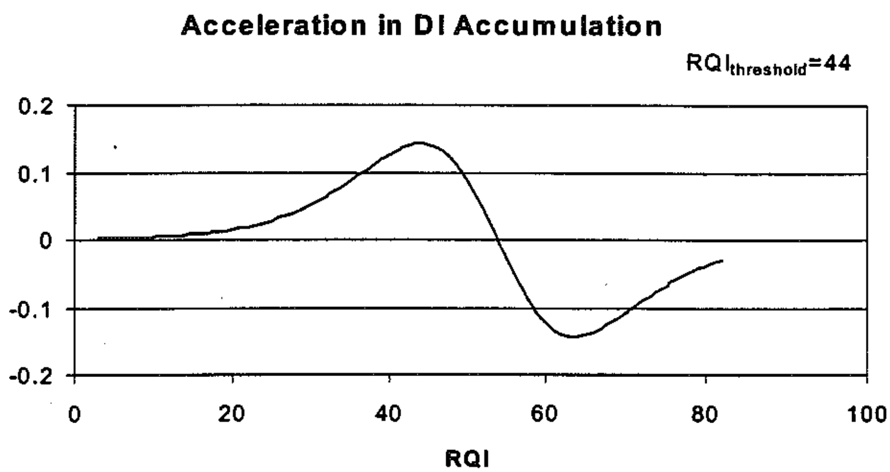


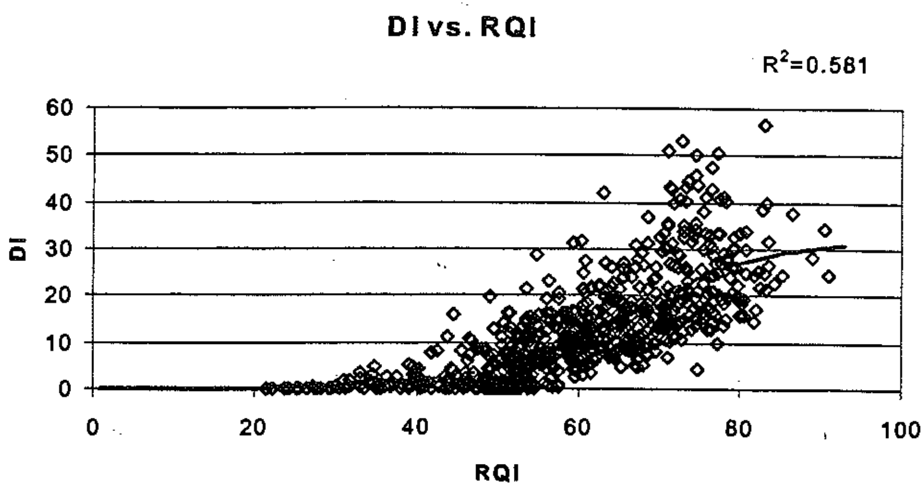
FIGURE 4.13 Relationship Between DI and RQI for Flexible Pavements from Data Set #3

TABLE 4.5 Regression Parameters and R^2-Values from the Second Data Set

Pavement Type	a	b	c	R^2
Rigid Pavements	25	-7.462	0.116	0.699
Composite Pavements	73	-6.593	0.109	0.511
Flexible Pavements	70	-7.517	0.160	0.448

TABLE 4.6 Regression Parameters and R^2-Values from the Third Data Set

Pavement Type	a	b	c	R^2
Rigid Pavements	36	-11.08	0.173	0.731
Composite Pavements	58	-7.272	0.143	0.603
Flexible Pavements	81	-7.140	0.135	0.507



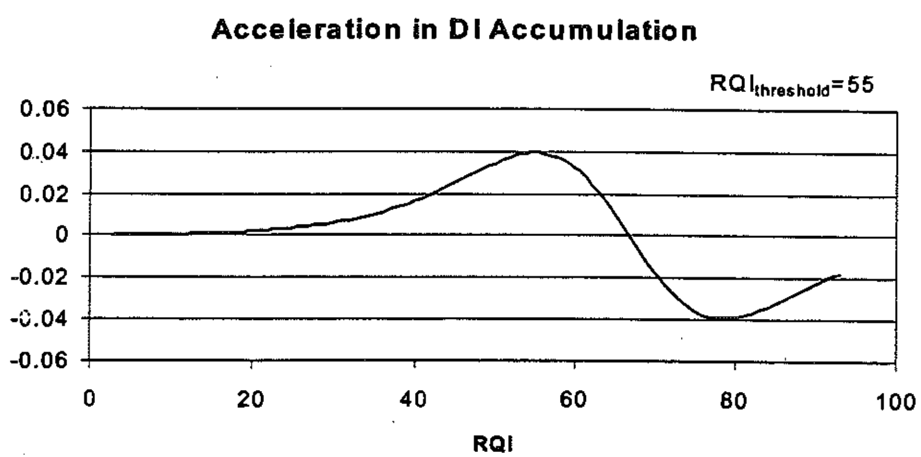
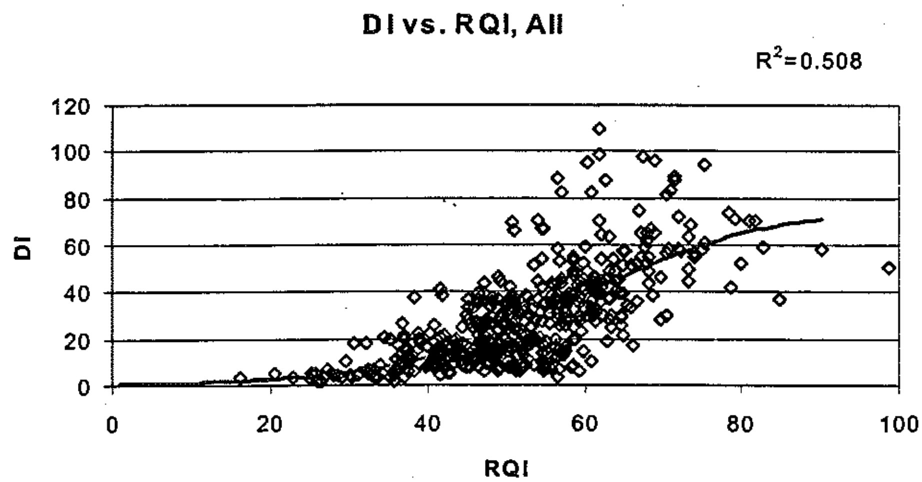


FIGURE 4.14 Relationship Between DI and RQI for Rigid Pavements from All Data Sets



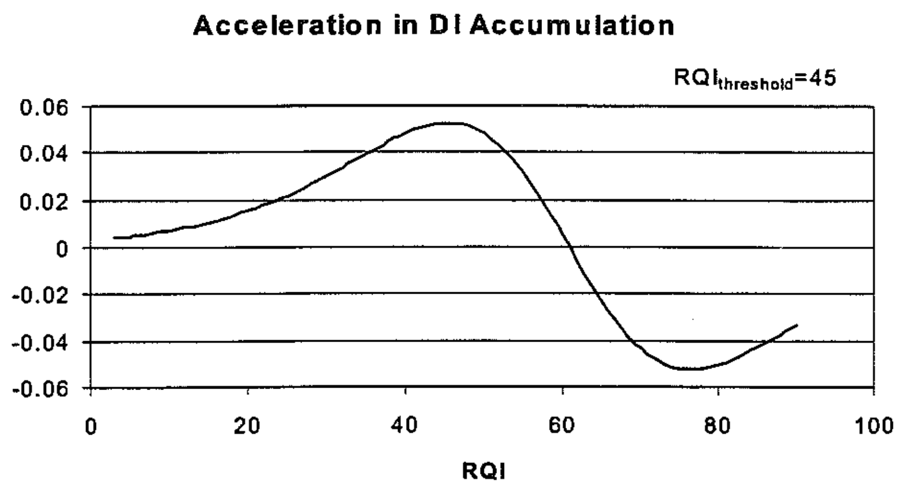
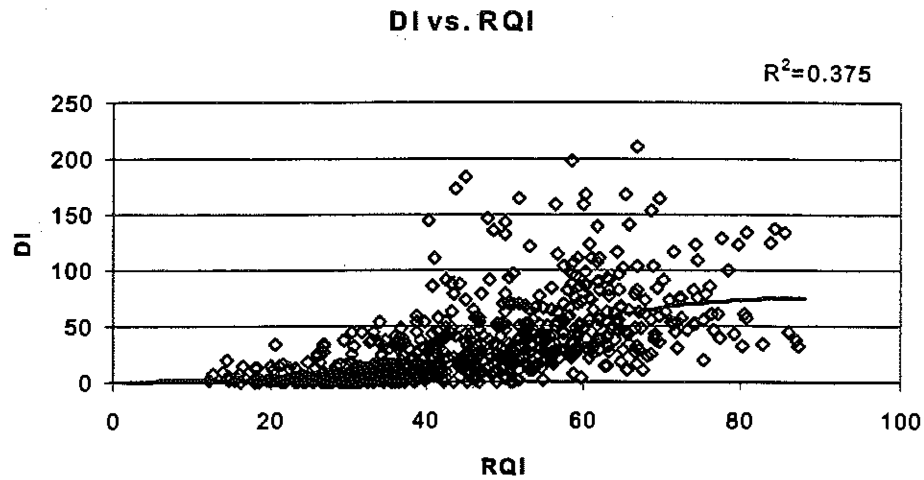


FIGURE 4.15 Relationship Between DI and RQI for Composite Pavements from All Data Sets



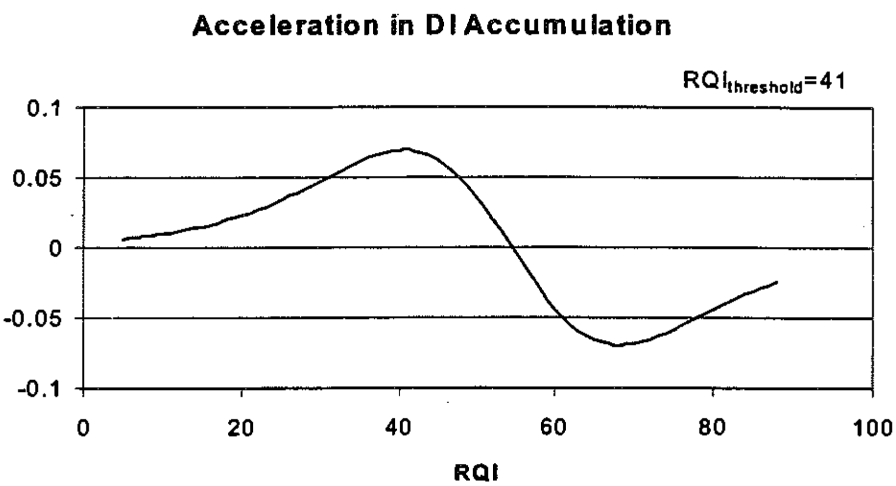


FIGURE 4.16 Relationship Between DI and RQI for Flexible Pavements from All Data Sets

TABLE 4.7 Regression Parameters and R^2-Values of Empirical Curves from All Data Sets

Pavement Type	a	b	c	R^2
Rigid Pavements	32	-7.393	0.112	0.581
Composite Pavements	77	-5.057	0.084	0.508
Flexible Pavements	78	-4.841	0.096	0.375

TABLE 4.8 Summary of Critical RQI Values

Pavement Type	First Data Set	Second Data Set	Third Data Set	All Data Sets
Rigid Pavements	57	54	57	55
Composite Pavements	44	48	42	45
Flexible Pavements	45	40	44	41

4.5.3 Interpretation of the Results

The above results indicate that rigid pavements have higher critical RQI-values than composite and flexible pavements. This seems to be caused by the following three factors.

First, the mechanisms of how the pavement surface becomes rough with time are different in rigid and flexible (or composite) pavements. For rigid pavements, the pavement surface becomes rough because of faulting, curling and warping. These distresses can happen without the existence of cracks. This means that the pavement surface can be rough without the existence of cracks, i.e., a rigid pavement can have high RQI-values without an increase in DI-value under the MDOT distress index pointing system. For flexible pavements, on the other hand, the pavement surface becomes rough mainly because of cracks. This difference makes rigid pavements exhibit high critical RQI-values.

The second factor could be the initial smoothness (or roughness) of a newly constructed or rehabilitated pavement. Generally, the initial roughness for rigid pavements is higher than that for flexible pavements because of the existence of joints. This high initial roughness may cause the critical RQI-values to shift up to a higher value.

Finally, the third factor could be the material behavior. Portland cement concrete is stronger than asphalt concrete; therefore, rigid pavements should be able to sustain higher dynamic axle loads than do flexible pavements. All the above-cited factors may lead to a higher critical RQI-value for rigid pavements.

4.6 PROBABILITY ANALYSIS ON THE RQI-DI RELATIONSHIPS

The critical RQI-values obtained from the DI-RQI curves are average values because they were determined based on the collective data obtained from many projects having different ages (i.e. different distress and roughness levels). The scatter of data points around the best-fit curve implies that critical values from individual projects are different, and that they scatter around the mean values determined from best-fit curves. Given that there is insufficient data from individual projects to determine project values, it would be useful to know how critical values of individual projects are distributed around the mean value.

Assuming that distress data points have a normal distribution at each RQI, 50% of DI data points lie between two values that are equal to the mean ± 0.675 σ at a given RQI-value, where σ = standard deviation of the DI. So, the upper and lower bands of data with a probability of 50% lie between curves with DI = mean ± 0.675σ. These upper and lower bands give critical values for the corresponding probability. The detailed results of this analysis are in Appendix B.

The results of the statistical analysis show a wide range of critical values. With a probability of 70%, threshold values range from 51 to 65 for rigid pavements, 40 to 57 for composite pavements, and 32 to 51 for flexible pavements. This indicates that critical values determined from lumping different projects could be used at the network level; however they are not accurate enough to be applied at the project level. This large variability in critical values comes from the fact that distress is caused not only by truck loads but also by many other factors. For example, some pavements could have a very low critical RQI-value if it has material problems. In this case, even if the pavement surface is smoothed at the time the critical RQI-value is reached, an increase in the rate of pavement damage cannot be reduced because the main cause of damage is not dynamic-load-related; rather it stems from other material-related factors. Such a pavement should therefore be subjected to a different maintenance action. For this reason, the timing when a pavement needs to be smoothed to lengthen its service life cannot be determined from the DI-RQI relationship. This timing can, instead, be determined from the relationship between surface roughness characteristics and theoretical pavement damage caused by dynamic loads. This requires the use of a mechanistic approach to the problem of truck-pavement interaction.

CHAPTER 5
NETWORK-LEVEL RELATIONSHIPS BETWEEN RIDE QUALITY INDEX AND DYNAMIC LOAD

Summary

In this chapter, the mechanistic approach was used to investigate the existence of a critical RQI-value at which pavement damage sharply increases. This was done by relating RQI to dynamic loading and theoretical pavement damage. Actual pavement surface profiles from 37 pavement projects in Michigan were input in the TruckSim™ computer program to generate dynamic axle loads. Good correlations were obtained between RQI and dynamic loading (DLC and 95th percentile dynamic load), and between RQI and pavement damage, with R^2 ranging from 0.85 to 0.95. Using the 4th power law, the relative damage from the 95th percentile dynamic load at different RQI levels was calculated. The corresponding reduction in pavement life for each roughness level was calculated using Miner's hypothesis. Based on these relationships, the critical RQI-values at which the reduction in pavement life sharply increases were determined for rigid, flexible and composite pavements. The lower bound for the critical RQI-value was taken as the minimum slope of the curve, beyond which the rate of reduction in pavement life starts increasing. This value was equal to 61, 50 and 47 for rigid, composite and flexible pavements, respectively. The upper bound for the critical RQI-value was taken as the maximum acceleration of the curve, at which the acceleration in the rate of increase in the reduction of pavement life is highest. This value was equal to 77, 70 and 66 for rigid, composite and flexible pavements, respectively.

5.1 INTRODUCTION

Dynamic wheel loads are generated by road roughness. The amplitude of dynamic loading is a function of road surface profile and vehicle parameters including the suspension type, tire, body mounts and vehicle speed. This dynamic loading amplification should lead to acceleration in pavement distress. In chapter 4, DI-RQI plots using MDOT PMS data showed that there is a reasonably good relationship between distress and roughness, and that at a critical value of roughness, distress increases sharply. This empirical result from in-service pavements confirmed that some profiles have roughness features that lead to an acceleration in pavement damage. However it was concluded that the corresponding RQI-value represents an average pavement behavior that could be used at the network level only. In this chapter, the relationship between dynamic axle load and road roughness is developed to mechanistically confirm the existence of a critical RQI-range leading to acceleration in pavement damage. For this analysis, actual surface profiles of 335 in-service pavement sections (0.1-mile long) from thirty-seven projects in Michigan were used to generate dynamic axle loads using the TruckSim™ truck simulation program. The predicted loads were then used to calculate the relative damage due to dynamic load amplification, based on the fourth power law, and the corresponding reduction in pavement life was calculated using mechanistic design principles.

5.2 SITE SELECTION AND DATA COLLECTION

For this analysis, the thirty-seven pavement projects selected randomly for developing the DI-RQI relationships (first data set) were used. Thirteen of the thirty-seven sites were rigid; fifteen were flexible; and nine were composite pavements. For these projects, RQI data and road surface profiles were obtained from the MDOT PMS database. These data were available for the period between 1992 and 1996. RQI data were available for 0.1-mile sections. Surface profile data were converted to ASCII files containing surface elevations at 3-in intervals.

5.3 RELATIONSHIP BETWEEN RQI AND DYNAMIC LOAD

In this approach, actual pavement surface profiles of the 333 (0.1-mile) sections from all 37 projects were used as input to the truck simulation program, TruckSim™; axle load time histories were generated from a typical 5-axle tractor-semi-trailer. The use of this truck type was based on the findings of the analysis in Chapter 3 that the drive axle of this truck and those from 2-axle and 3-axle single unit trucks have a good spatial correlation (i.e., their bouncing patterns are essentially parallel.) It should be noted that the combination of 5-axle tractor semi-trailers and 2- and 3-axle single unit trucks constitute more than 80% of the truck population in Michigan (see Figure 5.1).

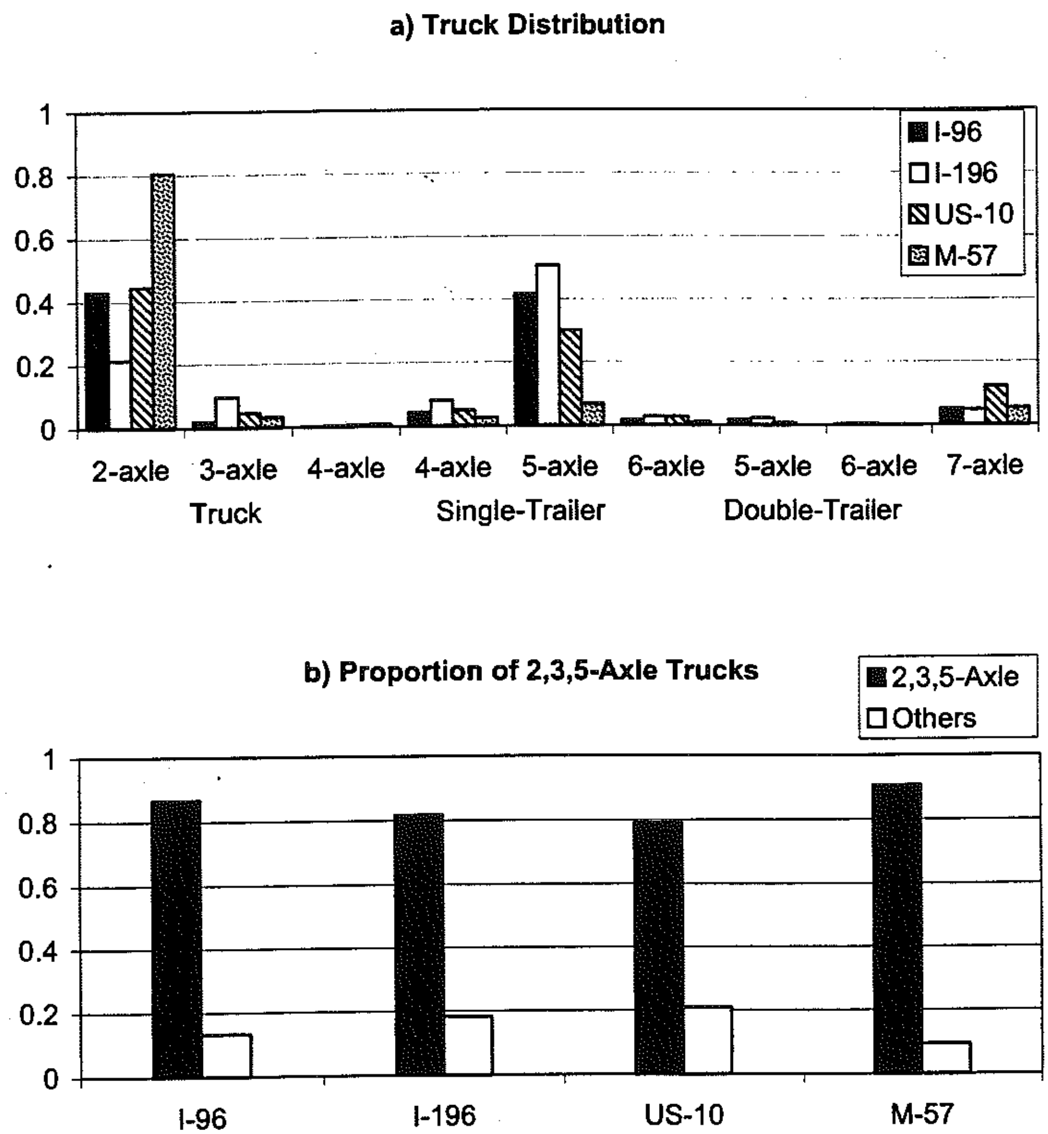


FIGURE 5.1 Truck Distribution for Different Highway Types in Michigan in 1999

To get dynamic load vs. RQI curves for each pavement type, several 0.1-mile sections for each roughness level (RQI=30, 40, 50, 60, 70, and higher than 80) were selected randomly from the 37 projects for a total 333 sections. Table 5.1 shows the number of samples used for each roughness level and pavement type. Dynamic axle load profiles (2nd axle of the tractor-semi-trailer) were generated along each 0.1-mile section using TruckSim™. From these dynamic axle-load profiles, DLC (Dynamic Loading Coefficient) and the 95th percentile axle load were calculated and plotted against the corresponding RQI-values. Figure 5.2 shows the relationship between DLC and RQI for rigid, flexible and composite pavements. The relationship between the 95th percentile axle load and RQI is shown in Figure 5.3. The 95th percentile dynamic load and the static load are illustrated in Figure 5.4. The dynamic amplification ratio is then calculated as follows:

$$Dynamic\ Amplification\ Ratio = \frac{95th\ Percentile\ Dynamic\ Load}{Static\ Load} = \frac{9786}{8500} = 1.15$$

The data were fit to fourth-order polynomial curves, with the resulting R^2-values ranging from 0.85 to 0.95. The DLC-RQI curves had slightly better R^2-values ($R^2 = 0.91$ to 0.95) than the 95th percentile axle load curves ($R^2 = 0.85$ to 0.93), with the highest values being for rigid pavements and the lowest values for flexible pavements. This is expected because of the variability in asphalt-surfaced pavements.

TABLE 5.1 Number of Samples (n) Used in the Analysis

Rigid Pavements	RQI	35	45	55	65	75	Higher than 80	Subtotal
	n	16	15	23	20	13	22	109
Flexible Pavements	RQI	20	30	40	50	60	Higher than 70	
	n	9	22	23	16	18	23	111
Composite Pavements	RQI	30	40	50	60	70	Higher than 80	
	n	12	19	24	21	12	25	113
Total								333

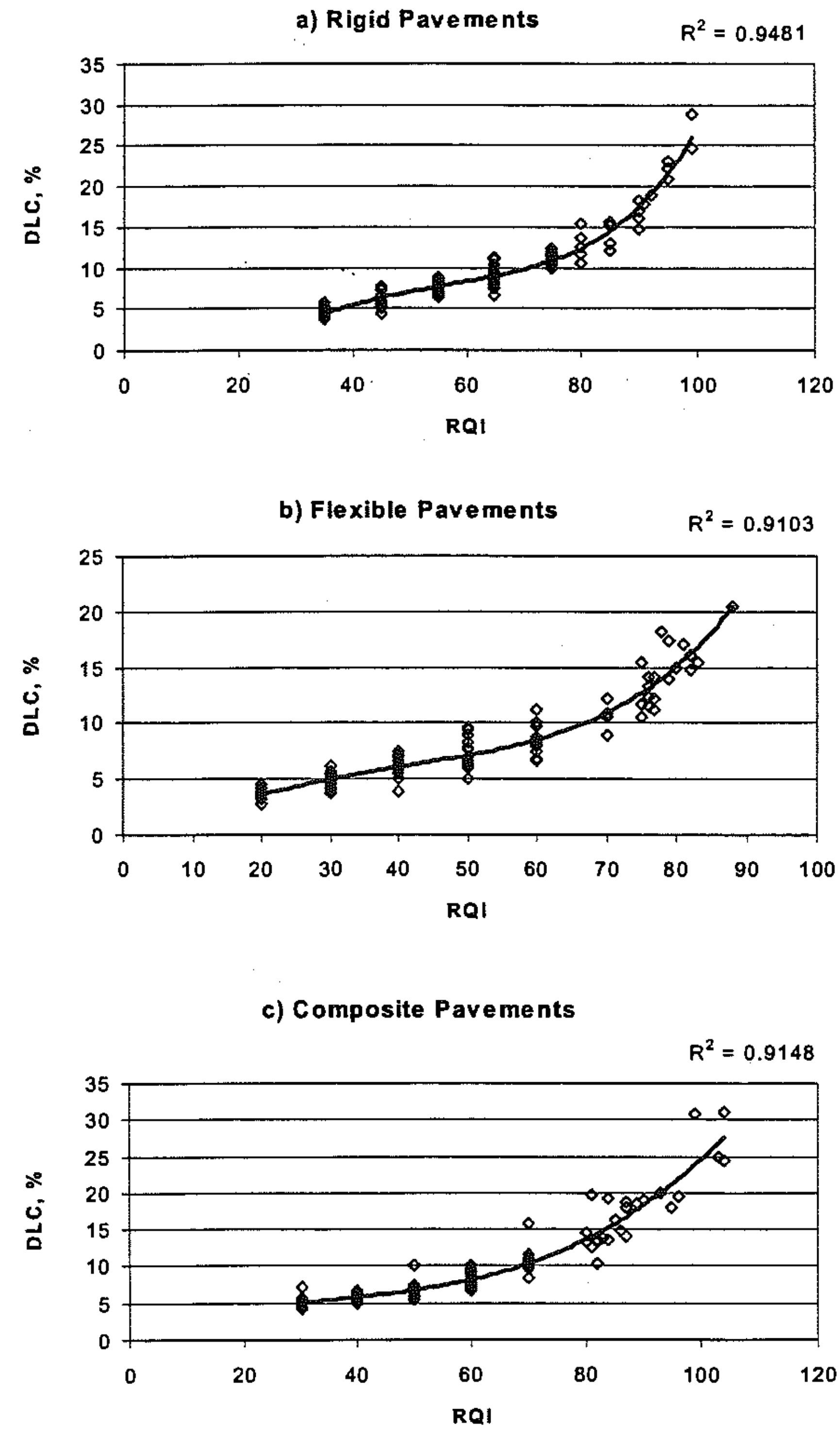


FIGURE 5.2 Dynamic Load Coefficient versus RQI Curve (n=333)

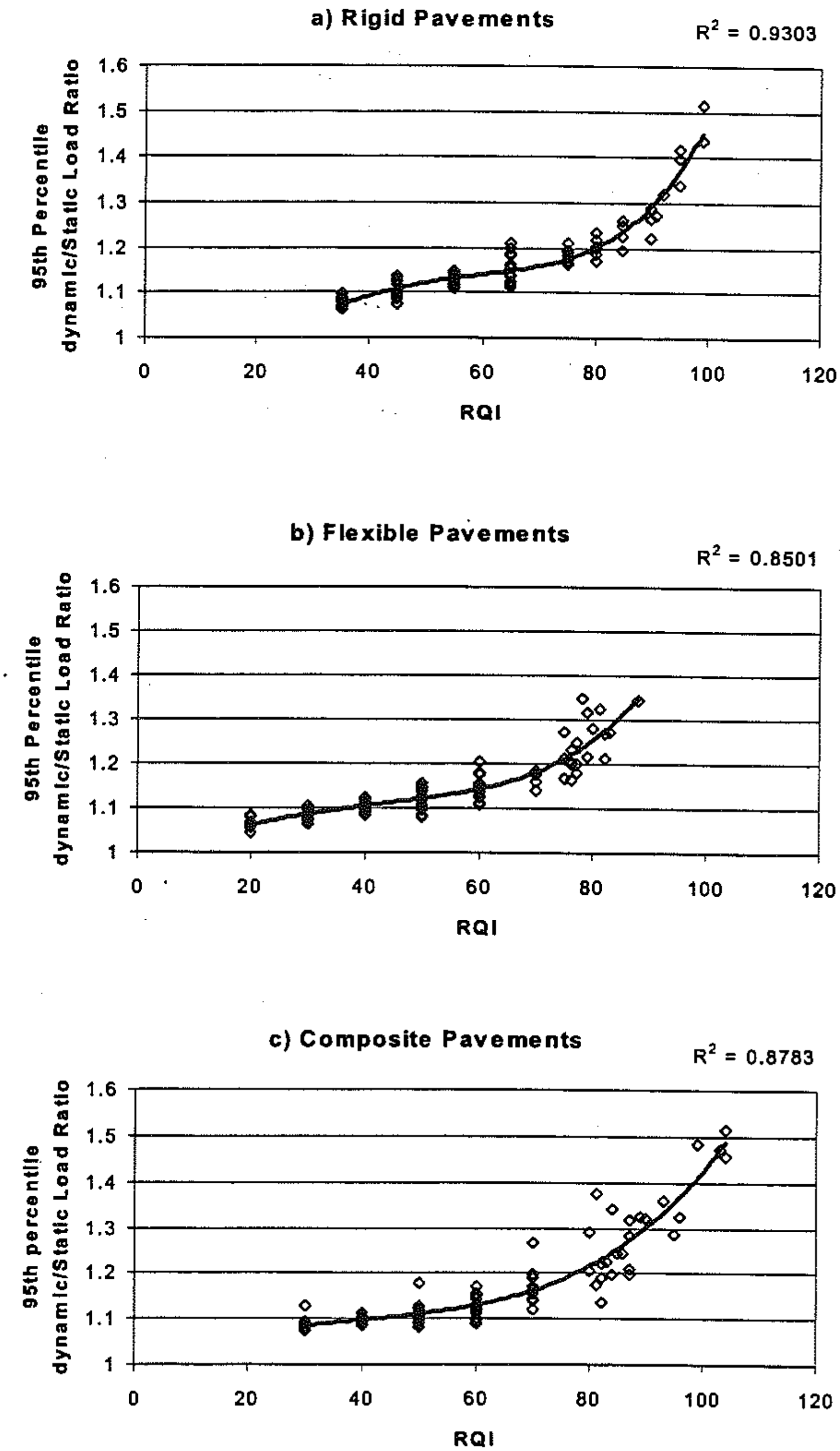


FIGURE 5.3 95th Percentile Dynamic Load (Normalized Relative to Static Axle Load) versus RQI Curve (n=333)

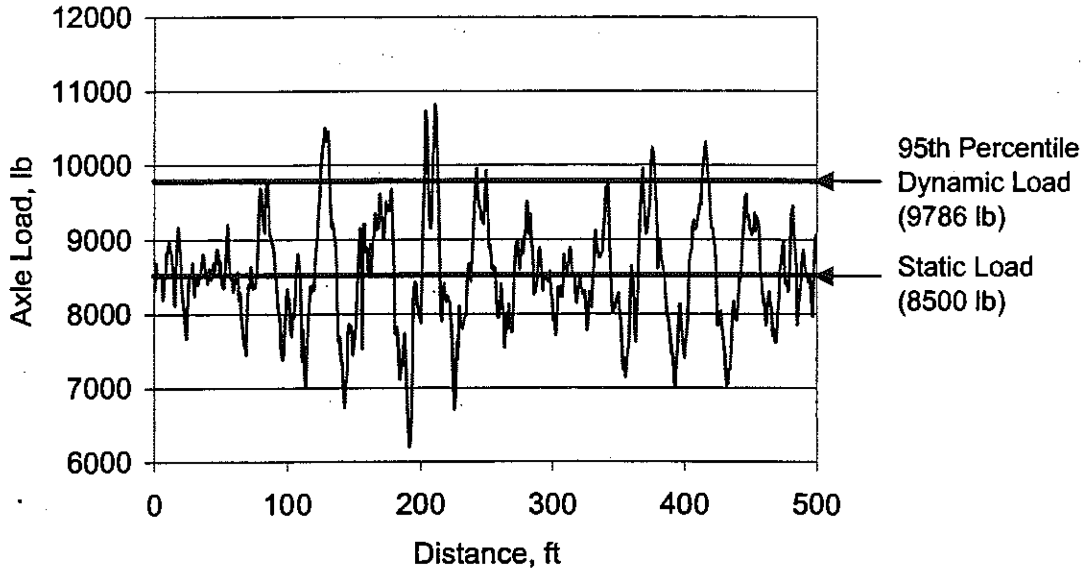


FIGURE 5.4 Illustration of 95th Percentile Dynamic Load and Static Load

In the mechanistic method of design, the equivalent axle load factor (EALF) defines the damage per pass to a pavement by a given axle relative to the damage per pass of a standard axle load, usually the 18-kip single-axle load. The number of passes of the standard axle load during the design period is defined as the equivalent single axle load (ESAL) (Huang, 1993). The EALF can be determined either based on empirical results (e.g., the AASHTO road test results) or theoretically using critical stresses and strains in the pavement and the appropriate failure criteria (e.g., fatigue or rutting criteria) (Huang, 1993). Previous studies (Deacon, 1996) indicate that the ratio of damages from different magnitudes of load is linearly related to the ratio of load magnitudes raised to some power, n, called the damage exponent. This is called a power law, with the 4^{th} power law (corresponding to $n = 4$) being widely used throughout the world. The AASHTO EALFs, which are used in MDOT current design procedure, also correspond to a power of about 4.

Using the above-described load equivalency concept, the relative damage induced in pavements by a dynamic load relative to a static load can therefore be expressed as the equivalent number of static load passes, and can be estimated using a power law:

$$Relative\,Damage = \left(\frac{L_{dynamic}}{L_{static}} \right)^n \tag{5.1}$$

where n is the damage exponent (typically, n = 3-5).

Using the 4^{th} power law, relative damages from the 95^{th} percentile dynamic load at different RQl levels were calculated and plotted in Figures 5.5, 5.6 and 5.7 for rigid, flexible and composite pavements, respectively. The corresponding R^2-values were between 0.83 and 0.92, with the higher values being for rigid pavements. All parameters and R^2 values for fitting curves are shown in Table 5.2. The general equation for these curves can be written as:

$$y = a \times RQI^4 + b \times RQI^3 + c \times RQI^2 + d \times RQI + e \qquad (5.2)$$

where y is the relative damage and a, b, c, and d are regression constants.

The theoretical percent reduction in pavement life can be calculated as (Miner, 1945):

$$Y = \textit{Percent Reduction in Pavement Life} = 100\% \, [1 - (\textit{Relative Damage})^{-1}] \qquad (5.3)$$

In the above equation, pavement life is defined as the number of load repetitions (passes) until failure, expressed in terms of the static load. Failure is used in a generic sense; i.e., it can be defined using any of different criteria, e.g., some percent cracking, or some level of distress points.

TABLE 5.2 Parameters and R^2-Values of Fitting Curves

		Parameters					R^2
		a	b	c	d	e	
Rigid Pavements	DLC	2E-06	-0.0003	0.0179	-0.1925	0.0	0.948
	95^{th} %tile DL	4E-04	-0.0621	3.5488	-45.6	8500	0.930
	Damage	4E-07	-8E-05	0.0045	-0.0728	1.0	0.918
Flexible Pavements	DLC	8E-07	-8E-05	0.0010	0.1843	0.0	0.911
	95^{th} %tile DL	1E-04	-8E-05	0.3294	24.7	8500	0.850
	Damage	2E-07	-2E-05	0.0007	0.0052	1.0	0.828
Composite Pavements	DLC	-3E-08	6E-05	-0.0062	0.2994	0.0	0.915
	95^{th} %tile DL	3E-05	0.0029	-0.6477	39.9	8500	0.878
	Damage	1E-07	-2E-05	0.0007	0.0029	1.0	0.878

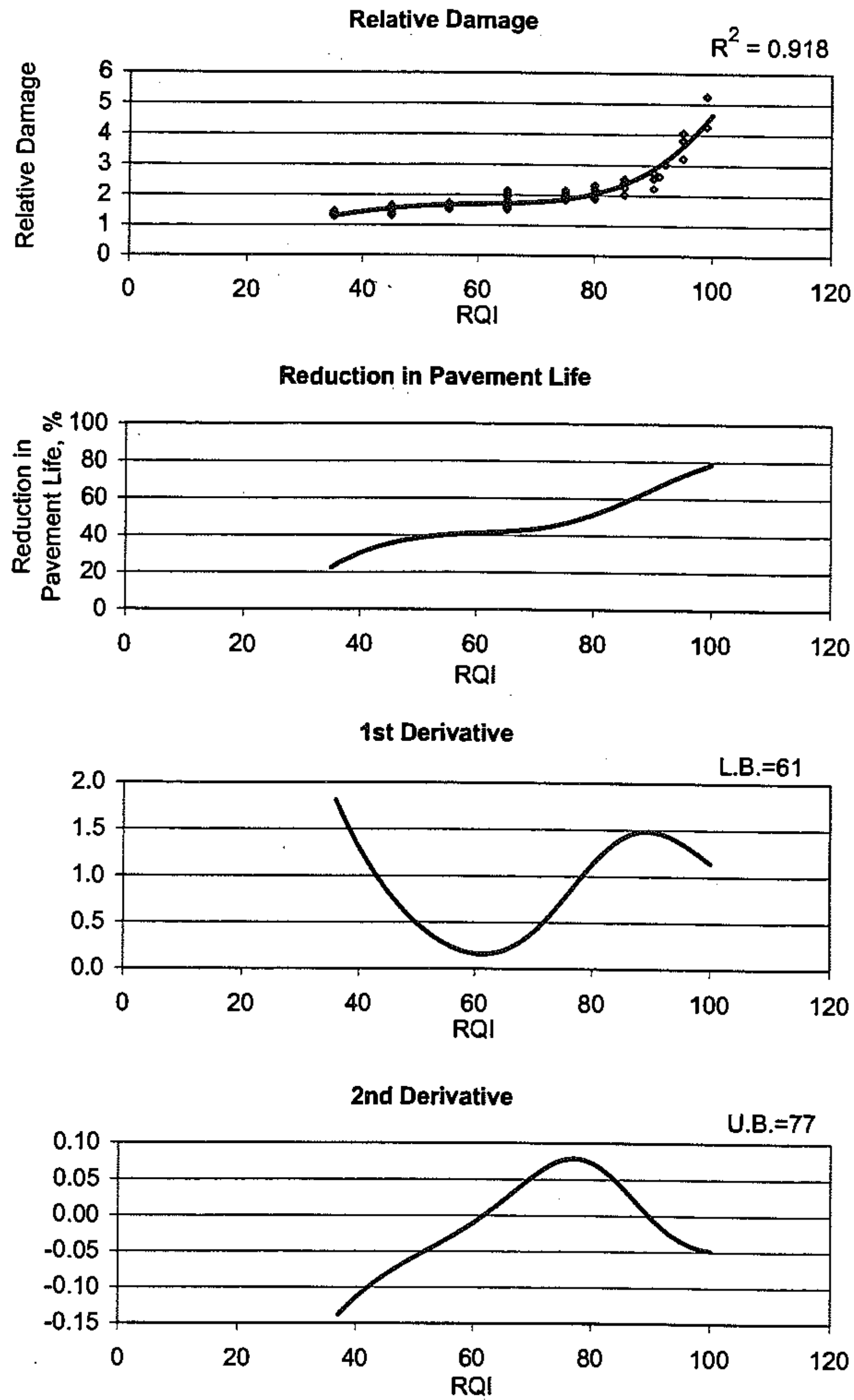


FIGURE 5.5 Relative Damage using 4th Power Law and Reduction in Pavement Life vs. RQI for Rigid Pavements (n=109)

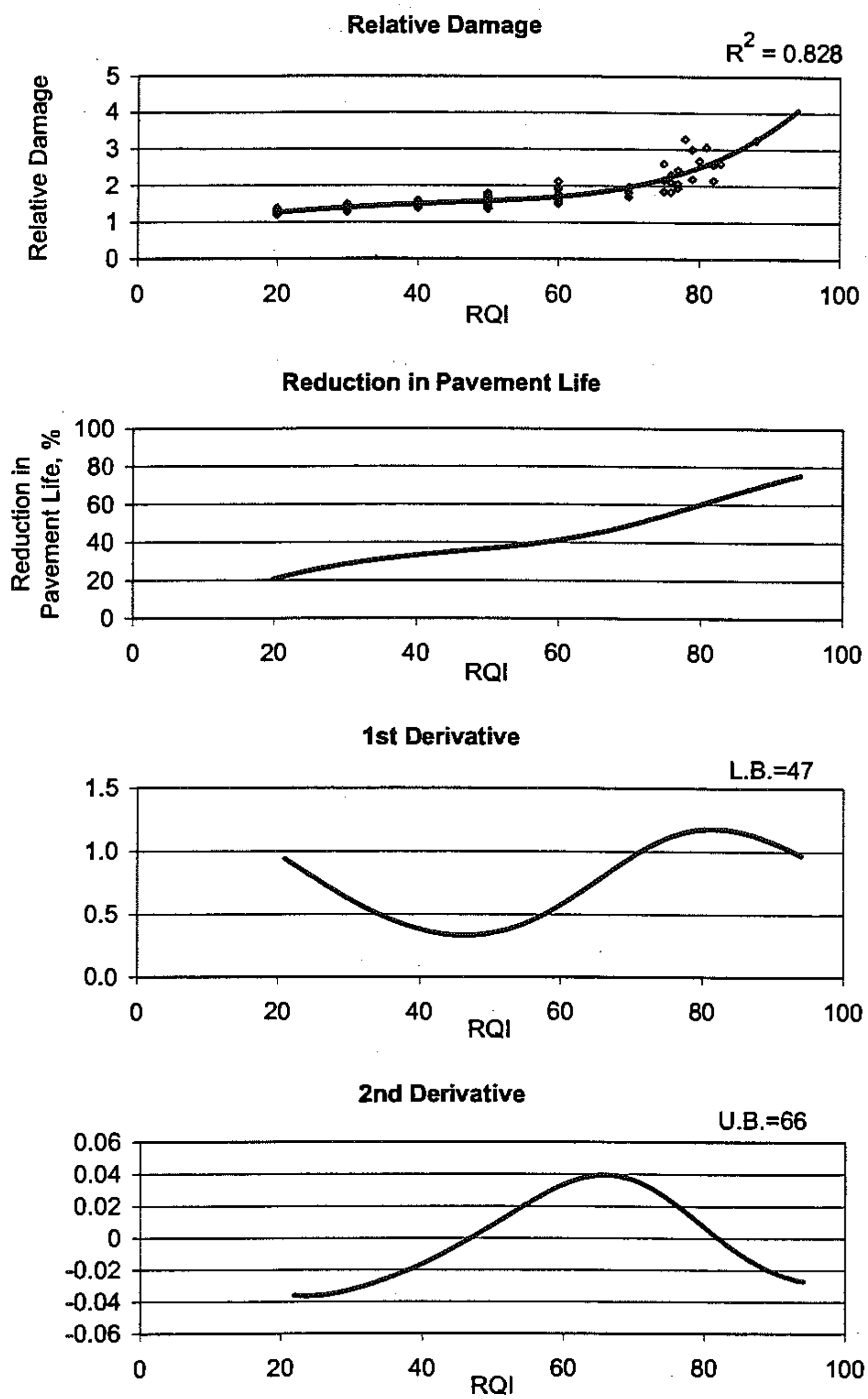


FIGURE 5.6 Relative Damage using 4th Power Law and Reduction in Pavement Life vs. RQI for Flexible Pavements (n=111)

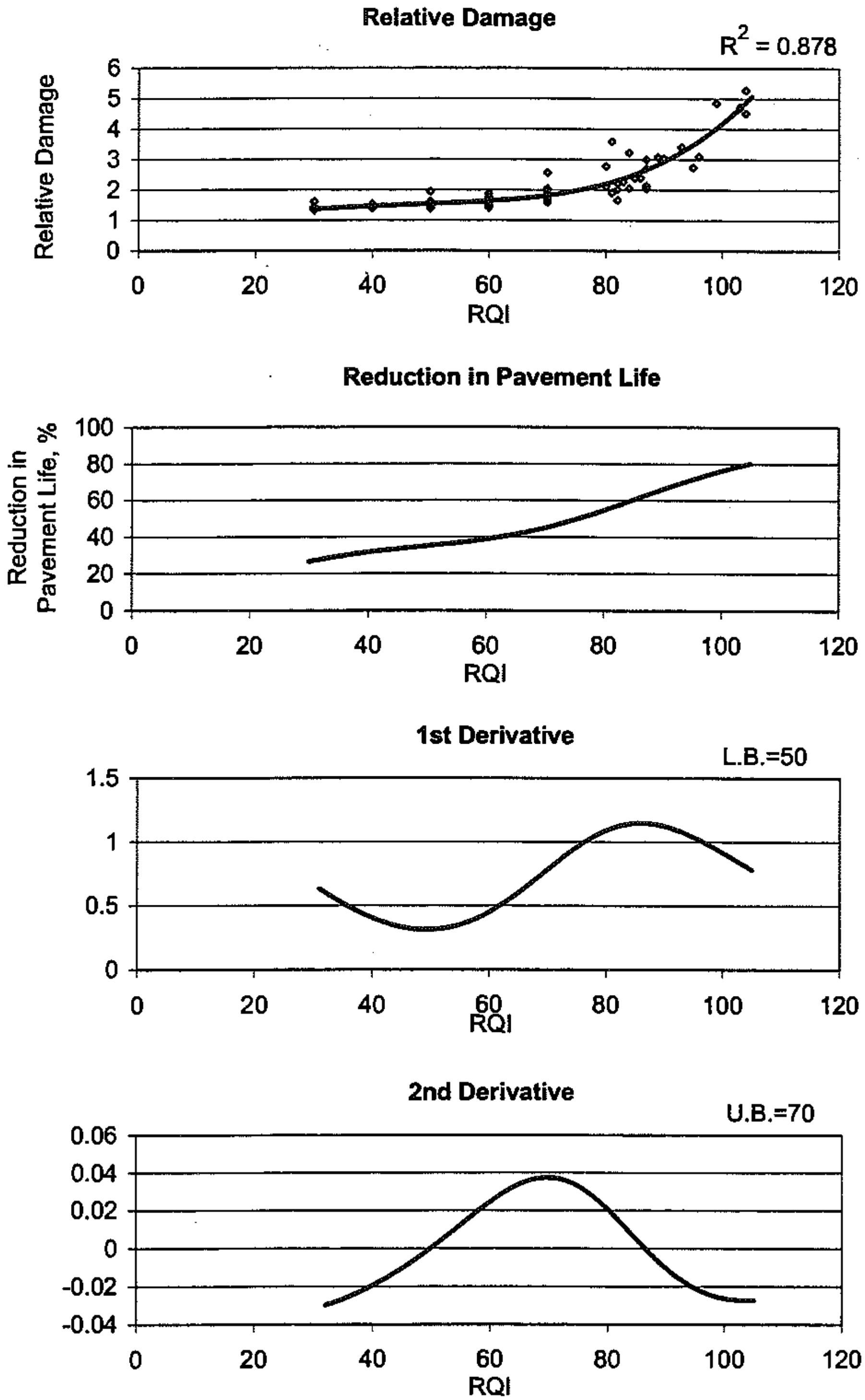


FIGURE 5.7 Relative Damage using 4th Power Law and Reduction Pavement Life vs. RQI for Composite Pavements (n=113)

A range of RQI-values where pavement damage sharply increases can be determined from the *derivatives* of the above function (Percent Reduction in Pavement Life) as follows:

(1) The *lower bound* for the critical RQI-value can be taken as the *minimum* of the first derivative (minimum slope of the curve), beyond which the rate of damage or reduction in pavement life starts increasing:

$$RQI_{min} = \min f'(RQI) \text{ where } f(RQI) = \frac{dY}{d(RQI)} \quad (5.4)$$

(2) The *upper bound* for the critical RQI-value can be taken as the *maximum* of the second derivative (maximum acceleration of the curve), beyond which the acceleration in damage or the rate of increase in the reduction of pavement life is highest:

$$RQI_{max} = \max f'(RQI) \text{ where } f'(RQI) = \frac{d^2Y}{d(RQI)^2} \quad (5.5)$$

The functions $f(RQI)$ and $f'(RQI)$ for each pavement type are also shown in Figures 5.4, 5.5 and 5.6. The function $f(RQI)$ decreases with increasing RQI down to a minimum point after which it starts to increase. The RQI-value where $f(RQI)$ is minimum can be taken as the *lower bound* value. The function $f'(RQI)$ vs. RQI increases with increasing RQI up to a maximum point beyond which it starts to decrease. The RQI-value where $f'(RQI)$ is maximum can be taken as the *upper bound* value.

The critical RQI-values using the above criteria are as follows:

Rigid pavements:	RQI = 61 (lower bound) ; RQI = 77 (upper bound).
Flexible pavements:	RQI = 47 (lower bound) ; RQI = 66 (upper bound).
Composite pavements:	RQI = 50 (lower bound) ; RQI = 70 (upper bound).

These values are not sensitive to the exponent used in the power damage law, as shown in Table 5.3.

At the lower bound value, reduction in pavement life starts to accelerate; while the acceleration is the highest at the upper bound value. Beyond the upper bound value, reduction in pavement life decelerates. The optimal timing for preventive maintenance action would be between the lower and upper bound values. However, the range in dynamic load for a given RQI value is wide. This makes it difficult to decide whether or not a particular pavement section that reaches the critical RQI range should be smoothed.

These critical RQI-values represent the overall behavior of pavements at the network level, and may not be applicable for a particular pavement project. Therefore, such values can be used for network-level pavement management, and not necessarily at the project level.

TABLE 5.3 Critical RQI Values from Different Power Laws

Pavement Type	Power Law	Lower Value	Upper Value
Rigid Pavements	4^{th} Power	61	77
	5^{th} Power	61	76
	6^{th} Power	62	75
Flexible Pavement	4^{th} Power	47	66
	5^{th} Power	47	64
	6^{th} Power	49	63
Composite Pavements	4^{th} Power	50	70
	5^{th} Power	52	69
	6^{th} Power	54	69

In the next chapter (Chapter 6), a new profile index that can predict whether or not a profile is prone to generate dynamic loading is developed. This new profile index could be used to determine the timing at which preventive maintenance action is necessary to reduce dynamic loads.

Finally, the lower-bound values are in reasonable agreement with the field-derived values based on surface distress accumulation (Chapter 4), with field-derived values being lower than the dynamic-load-based values. This can be explained by the fact that distress accumulation in in-service pavements is due to many factors such as structural and material integrity of the pavement components and environmental effects. These additional factors will cause an earlier increase in distress. Since the field-derived values are based on the rate of increase in distress, they are bound to be lower than those predicted mechanistically solely on the basis of the increase in dynamic loading.

CHAPTER 6
DEVELOPMENT OF A NEW ROUGHNESS INDEX FOR IDENTIFYING PROFILES LIKELY TO GENERATE HIGH DYNAMIC LOADS

Summary

While RQI is a good general indicator of dynamic loading, with plots of dynamic axle load against RQI having high R^2-values (ranging from 0.850 to 0.948), a wide range of dynamic loads can exist for a given RQI value. This makes it difficult to decide whether a particular pavement section at the critical RQI-value needs to be smoothed. To solve this problem, a new index (Dynamic Load Index), which better represents dynamic truck-axle loading was developed from the profile PSD curve. DLI is calculated as a weighted index of variances of the profile elevation in the frequency ranges 1.5-4 Hz and 8-15 Hz. The first frequency range is where truck body bounce occurs, while the second frequency range corresponds to axle bounce. The analysis showed a very good relationship between DLI and dynamic load. The new index can differentiate between profiles that generate high dynamic loads and those having the same RQI but generating low dynamic loads. Most importantly, the use of the DLI index negates the need for running a truck simulation program. This makes it possible to decide whether a particular pavement with a given surface profile needs smoothing based on the DLI-value.

6.1 INTRODUCTION

The RQI is a good general indicator of dynamic loading. However, the range in dynamic truck axle loads for a given RQI value is wide. This range exists because RQI was developed based on passenger car response to pavement surface. This makes it difficult to decide whether or not a particular pavement section should be smoothed based on RQI because damage in pavements is caused mainly by heavy truck axle loads. An accurate prediction of roughness level that will excite trucks requires the evaluation of dynamic truck axle loading likely to be generated by the profile characteristics of the individual pavement section. One way to predict dynamic axle loads, given a surface profile, is to use a truck simulation computer program. This would require some knowledge of truck dynamics and a minimum fluency in truck parameters for specific components such as the suspension system, the chassis and the tires. Therefore it would be impractical for a state highway agency such as MDOT to adopt such an approach. An alternative method would be to determine the relative increase in dynamic axle loads directly from the profile itself, since dynamic axle loading is a function of the pavement surface profile characteristics.

In this chapter, a new roughness index (Dynamic Load Index) is developed. This new index negates the need for running a truck simulation program to determine whether a pavement profile is friendly/unfriendly from a dynamic loading aspect. The DLI makes it possible to decide whether a particular pavement with a given surface profile needs smoothing or not.

6.2 DEVELOPMENT OF A DYNAMIC-LOAD-BASED ROUGHNESS INDEX

While plots of dynamic axle load against RQI have high R^2-values ranging from 0.850 to 0.948, as shown in Figures 5.2 and 5.3, they show a wide range of dynamic load magnitudes for a given RQI value. This is because RQI is calculated from a wide range of wavelengths ranging from 2 ft to 50 ft. According to the literature, various experimental and theoretical studies have shown that vehicle bounce occurs in the range of frequencies between 1.5 and 4 Hz, and axle bounce occurs between 8 and 15 Hz (OECD, 1992). These frequencies correspond to wavelengths between 22 and 59 ft and between 6 and 11 ft at a vehicle speed of 60mph. The remaining wavelength ranges have little to do with dynamic truck-axle loads. Thus, if an index is focused on only the above wavelengths, i.e., 22-59 ft and 6-11 ft, it could have a better correlation with dynamic axle load than RQI.

The detailed formulation of the new index is described in subsequent sections. However, the following discussion assumes the existence of such index, from here on called the Dynamic Load Index (DLI). Furthermore, it is assumed that the index uses the two critical wavelengths identified above.

Figure 6.1 shows the wavelength ranges used for the RQI and DLI. It can be seen that there are gaps between the ranges of wavelengths used in calculating the RQI and DLI. These gaps help explain the possibility of obtaining an inflated RQI-value because of noise in the profile in the range of 2 to 6 ft and 11 to 22 ft. On the other hand, if the profile contains high elevations at wavelengths greater than 50 ft, the RQI value will be deflated.

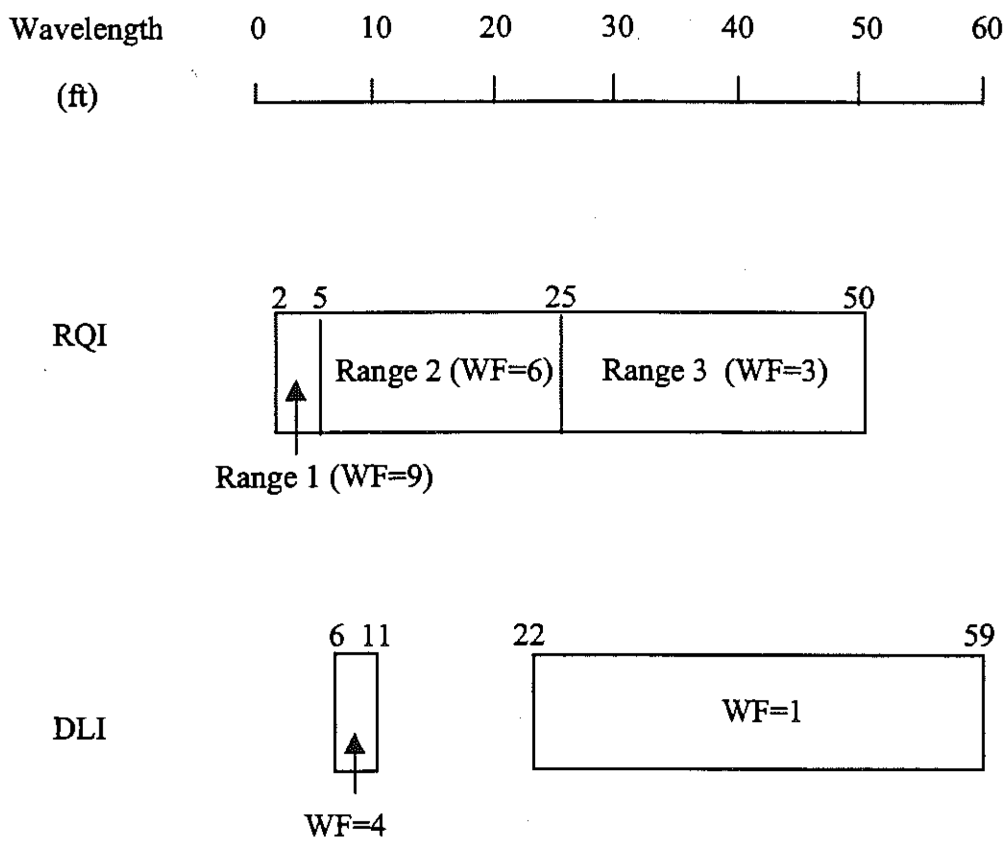


FIGURE 6.1 Wavelength Ranges used for RQI and DLI

Figures 6.2 (a) and 6.3 (a) show surface profiles of two 0.1-mile rigid pavement sections that have the same RQI (equal to 65) but different DLC-values. Recall that the DLC is the dynamic load coefficient, which is a measure of the magnitude of the dynamic variation of axle load over a given surface profile, and is calculated as the ratio of the standard deviation of the dynamic load fluctuations over the static load. The DLC-value for a perfectly smooth pavement surface would theoretically be zero. DLC-values less than 8% indicate moderately smooth pavements, while DLC-values higher than 10% are considered to be indicative of moderately rough pavements, and DLC-values higher than 15% indicate very rough pavement surfaces. Cases of DLC-values higher than 20% could occur when the truck is equipped with an unfriendly suspension system such as the walking-beam type (an older, rugged suspension system that is used mainly in off-road trucking nowadays), with extreme values possibly reaching 30 to 35% (Gillespie et al, 1993).

Section #1 (WB US-10, CS18024, M.P. 7.0-7.1) has an "unfriendly" surface profile with a DLC-value of 11.3%. On the other hand, Section #2 (EB US-10, CS18024, M.P. 2.3-2.4) has a DLC-value of 6.6%, and therefore has a "friendly" surface profile. The corresponding axle load profiles (2nd axle load in 5-axle semi-trailer) are shown in Figures 6.2 (b) and 6.3 (b). The power spectral density (PSD) curves of the dynamic axle load are shown in Figures 6.2 (c) and 6.3 (c). These figures show that in Section #1, large axle loads occurred at frequencies between 1.5 and 4 Hz while there was no such amplification in Section #2. At frequencies between 8 and 15 Hz, both sections show small dynamic loading; while at all other frequencies, the dynamic axle load is negligible. These figures clearly illustrate that dynamic truck axle loading is related to profile elevations having a wavelength between 22 and 59 ft and between 6 and 11 ft. As stated above, these frequencies/wavelengths excite the truck body bounce and axle bounce, respectively.

Figures 6.2 (d) and 6.3 (d) show PSD curves of the two profiles. In Figure 6.4, PSD curves of the two profiles are plotted together, with the two wavelength ranges that excite the truck bounce marked on the figure. The figure shows that at these wavelength ranges (22-59 and 6-11 ft), the PSD curve of Section #1 has much higher amplitude relative to Section #2. The areas under the profile PSD curve between wavelengths of 22 and 59 ft are 4.66 in^2 for Section #1 and 1.37 in^2 for Section #2. Areas between wavelengths of 6 and 11 ft are 0.211 in^2 for Section #1 and 0.121 in^2 for Section #2. These areas represent the amplitudes of the surface elevations for the critical wavelength ranges. The results indicate that Section #1 has a much larger area for wavelengths between 22 and 59 ft than Section #2. This high amplitude of the 22 to 59 ft-long waves for Section #1 excited the body bounce of the truck and lead to high dynamic axle loads.

The two profiles and the wavelength ranges (2-5, 5-25 and 25-50 ft) that are used for the calculation of RQI are shown in Figure 6.5. Figure 6.6 shows DLC values and areas under PSD curves for each wavelength range for both sections. These two figures show that the profile of Section #1 contains high roughness at the high range of wavelengths (25-50 ft). On the other hand, the profile of Section #2 contains high roughness at the low range of wavelengths (2-5 ft).

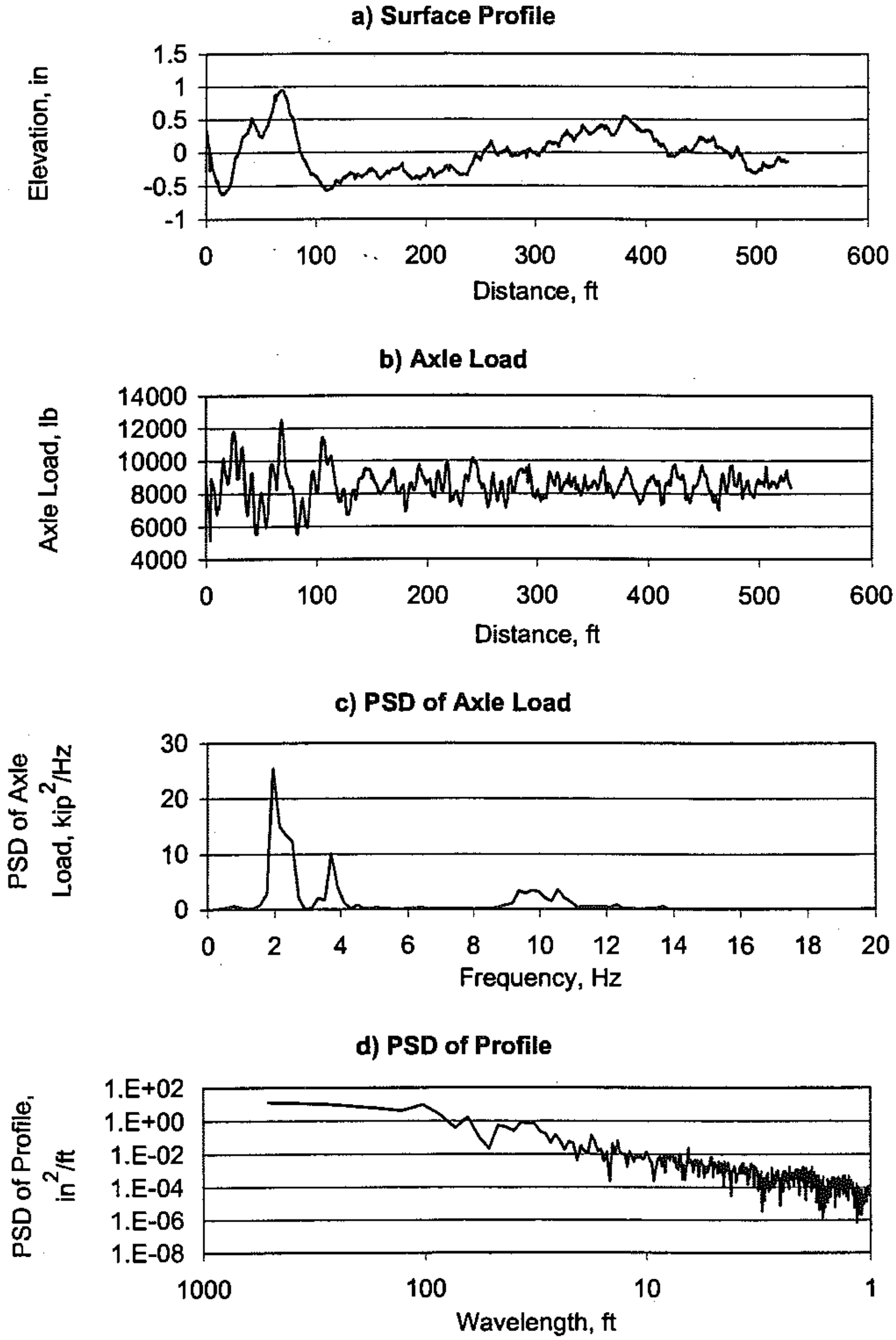


FIGURE 6.2 Surface Profile and Axle Load in Space and Frequency Domain for Section #1 (WB US-10 CS 18024 MP. 7.0-7.1)

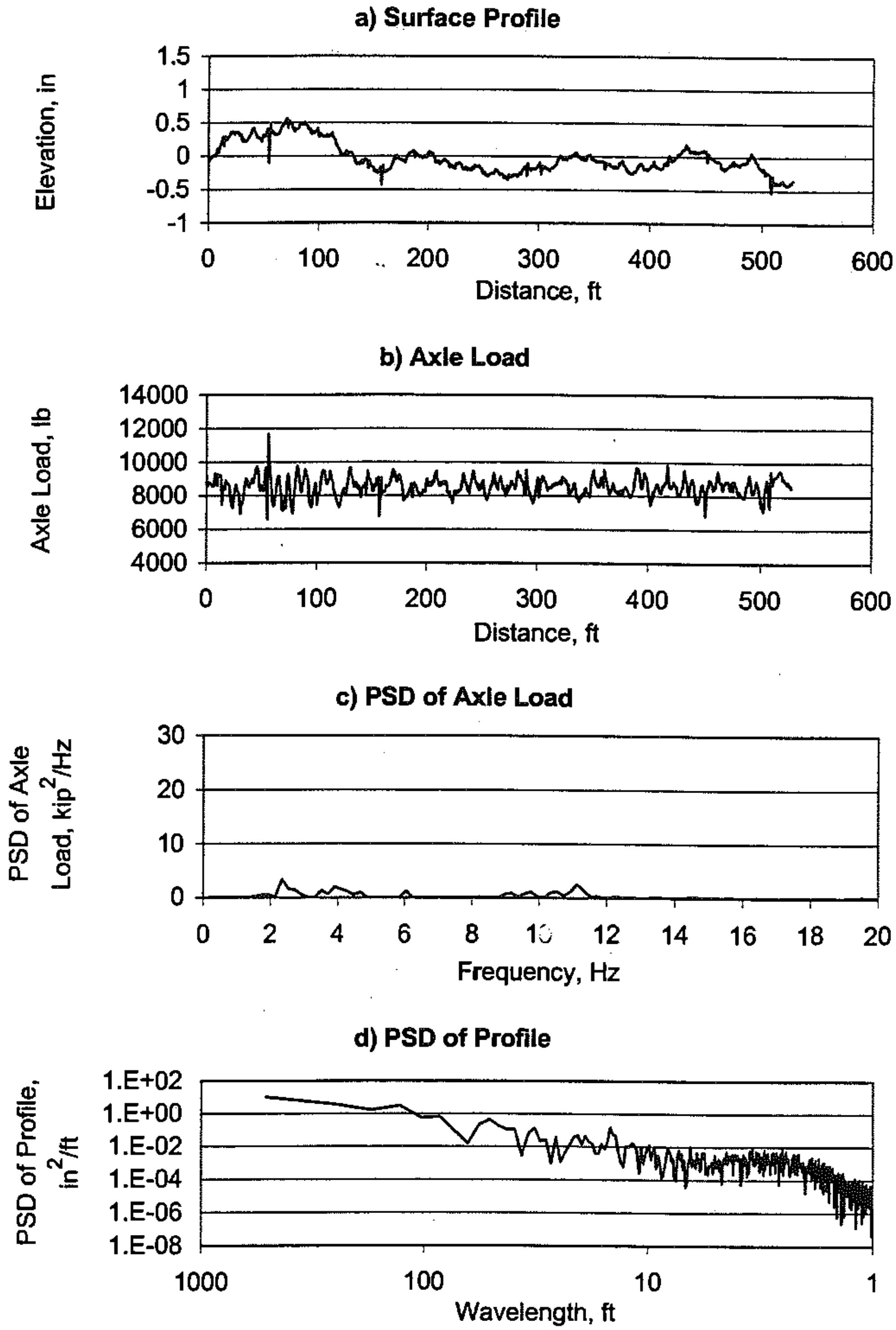


FIGURE 6.3 Surface Profile and Axle Load in Space and Frequency Domain for Section #2 (EB US-10 CS 18024 MP. 2.3-2.4)

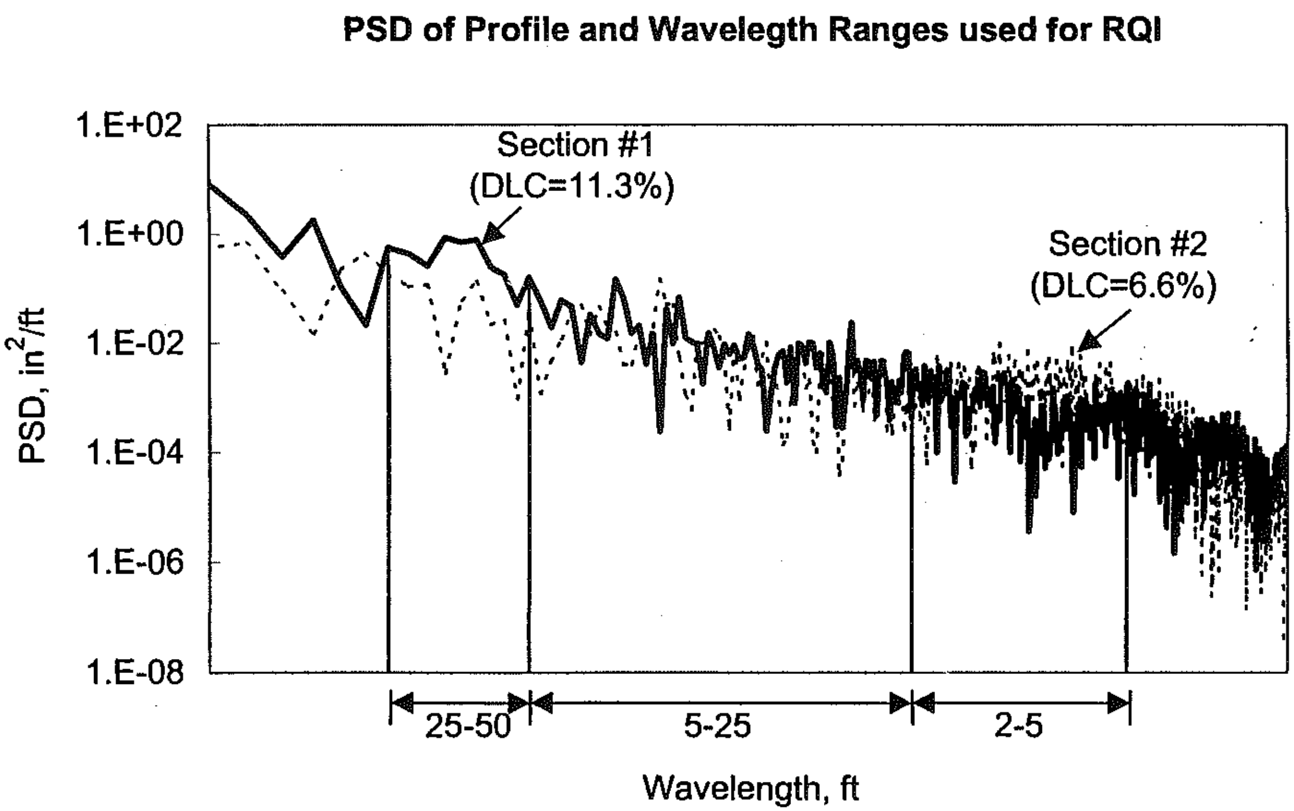


FIGURE 6.4 PSD of Profiles for Section #1 and #2 and Wavelength Ranges used for DLI

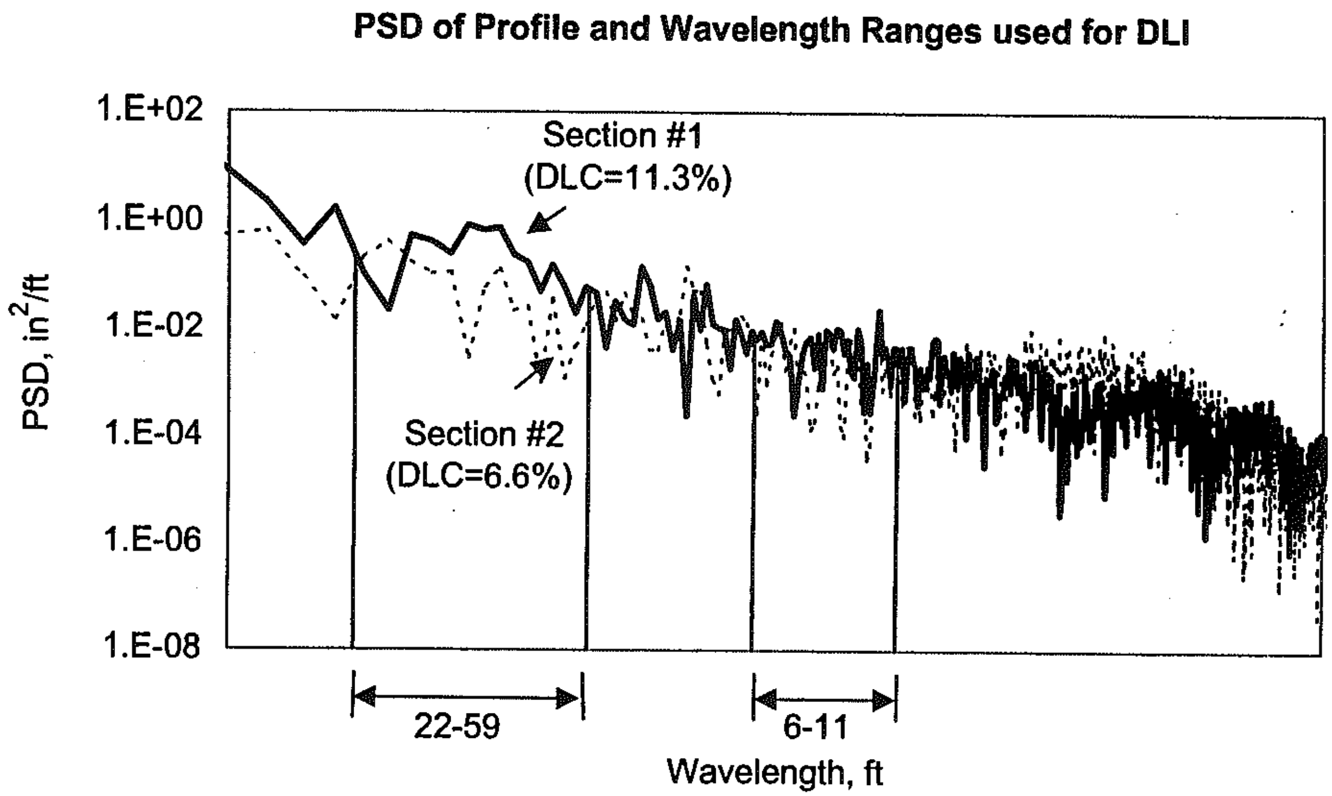


FIGURE 6.5 PSD of Profiles for Section #1 and #2 and Wavelength Ranges used for RQI

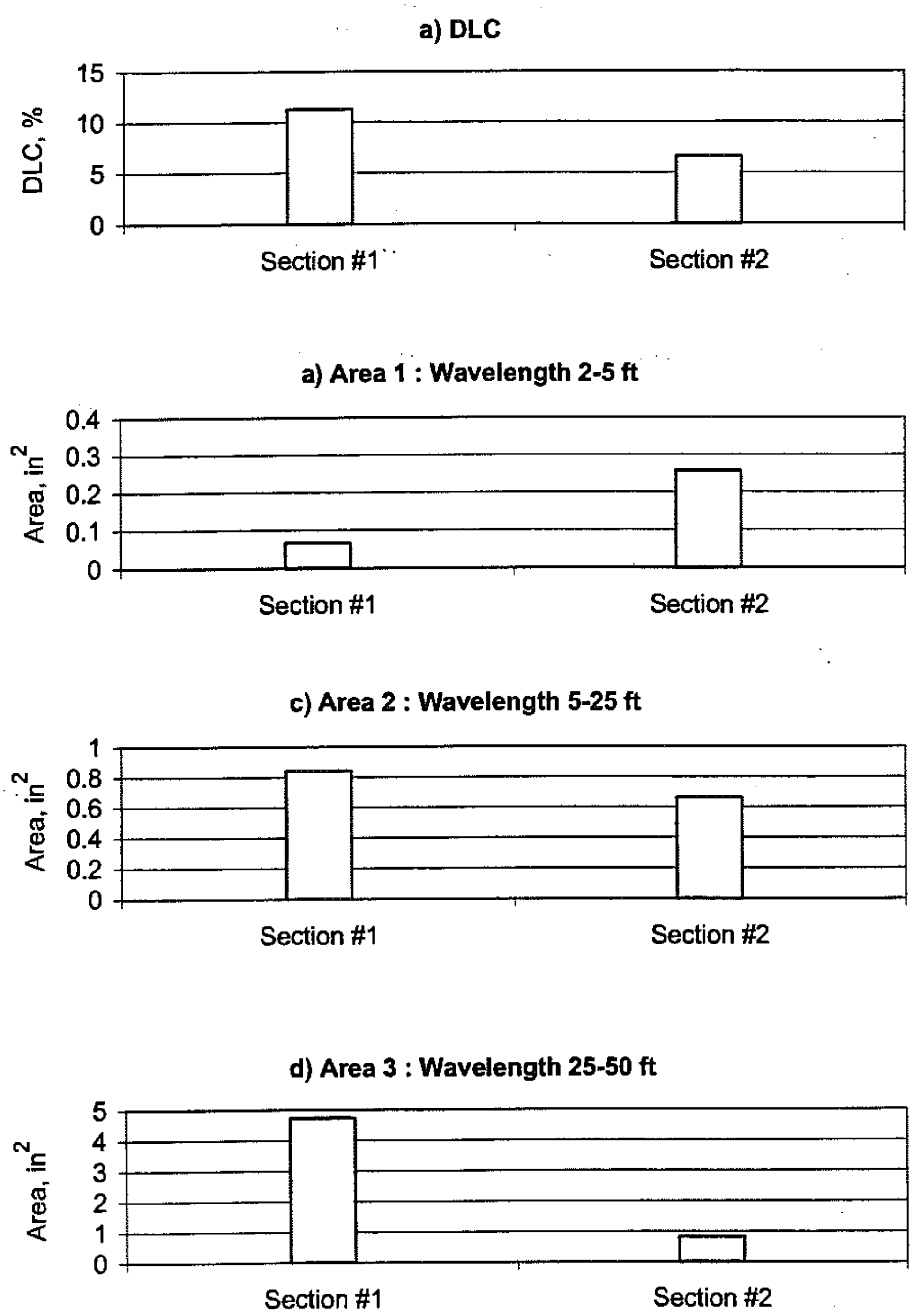


FIGURE 6.6 Distribution of Wavelength Content for Two Sections in Terms of the Ranges Used in the Calculation of the RQI

This range of wavelengths does not excite the truck; hence the RQI-value for Section #2 is inflated from the point of view of dynamic loading because of this noise. Note that Section #2 does not contain much roughness in the range of wavelengths between 25 and 50 ft, which does excite the truck. The roughness contents in the wavelength range of 2-5 ft for Section #1 and in the wavelength range of 25-50 ft for Section #2 explain why both sections have the same RQI-value.

6.2.1 Formulation of the New Profile Index

According to linear random vibration theory, the PSD of truck response is obtained by multiplying the square of the truck response function by the PSD of the surface profile. Figure 6.7 shows this relationship schematically. The variance of truck response can be expressed mathematically as (Newland, 1984),

$$V_y = \frac{1}{v} \int |G(w)|^2 S_x(\frac{w}{v}) dw = \int |G(w)|^2 S_x(w) dw \qquad (6.1)$$

where V_y is the variance of truck dynamic load;

$G(w)$ is the truck response function;

$S_x(k = \frac{w}{v})$ is the PSD function of the surface profile;

w is circular frequency;

v is vehicle speed;

k is wavenumber; and

$S_x(w) = \frac{1}{v} S_x(k = \frac{w}{v})$ is the PSD of the temporal input to the truck suspension system

The area under the PSD curve of the profile at a given frequency range can be approximated as the profile variance for that frequency range. If only the frequency ranges of 1.5-4.0 and 8.0-15.0 Hz, which correspond to truck body and axle bounces, are considered, V_y can be approximated as,

$$V_y \approx |G(w_1)|^2 V_1 + |G(w_2)|^2 V_2 \qquad (6.2)$$

where $G(w_1)$ is the peak value of truck response function at the frequency range of 1.5-4.0 Hz;

$G(w_2)$ is the peak value of truck response function at the frequency range of 8.0-15.0 Hz;

V_1 is the variance of the elevation in the frequency range of 1.5-4.0 Hz; and

V_2 is the variance of the elevation in the frequency range of 8.0-15.0 Hz.

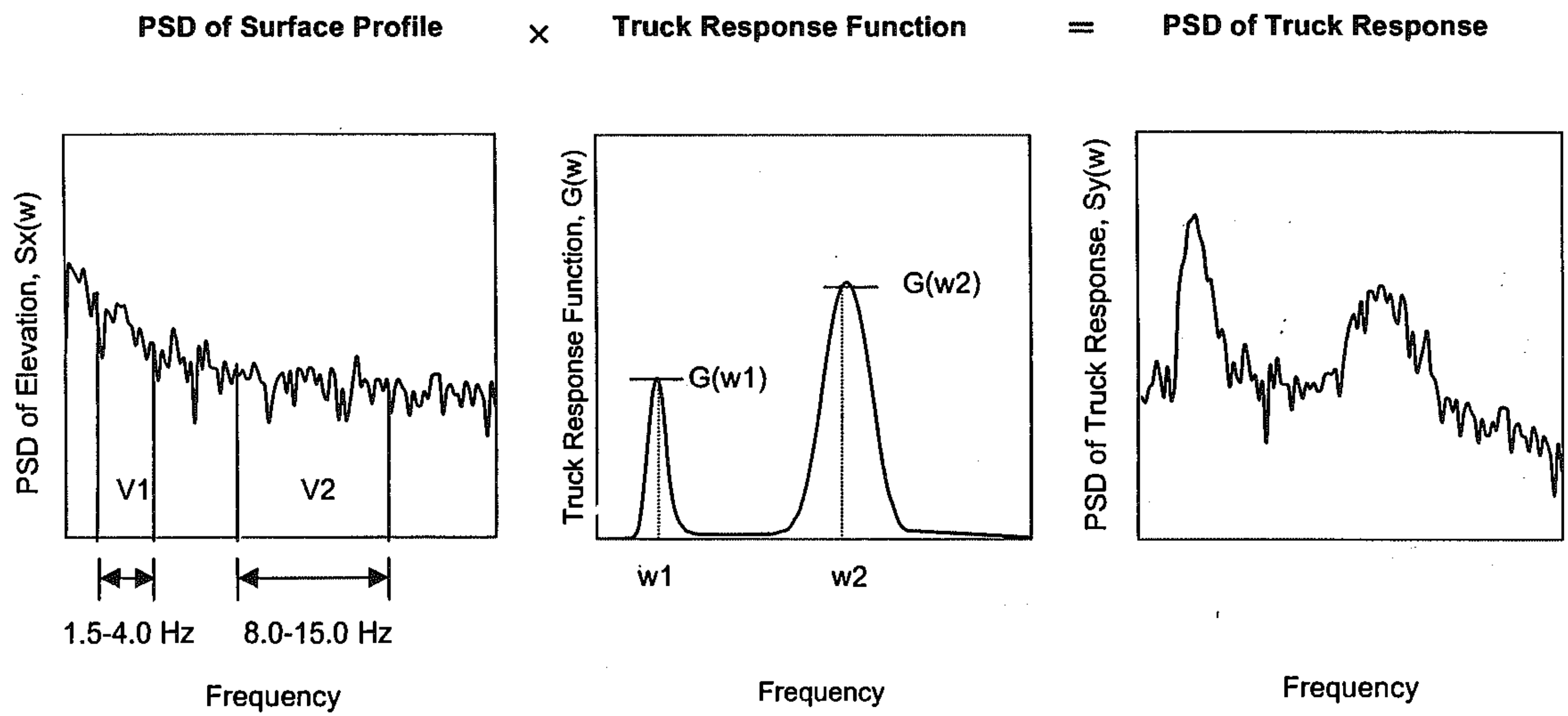


FIGURE 6.7 Schematic Figures of PSD of Surface Profile, Truck Response Function and PSD of Truck Response

The standard deviation of truck response is therefore,

$$\sigma_y = \sqrt{V_y} = \sqrt{|G(w_1)|^2 V_1 + |G(w_2)|^2 V_2} \tag{6.3}$$

Equation (6.3) suggests the following form for the new roughness index, called Dynamic Load Index (DLI).

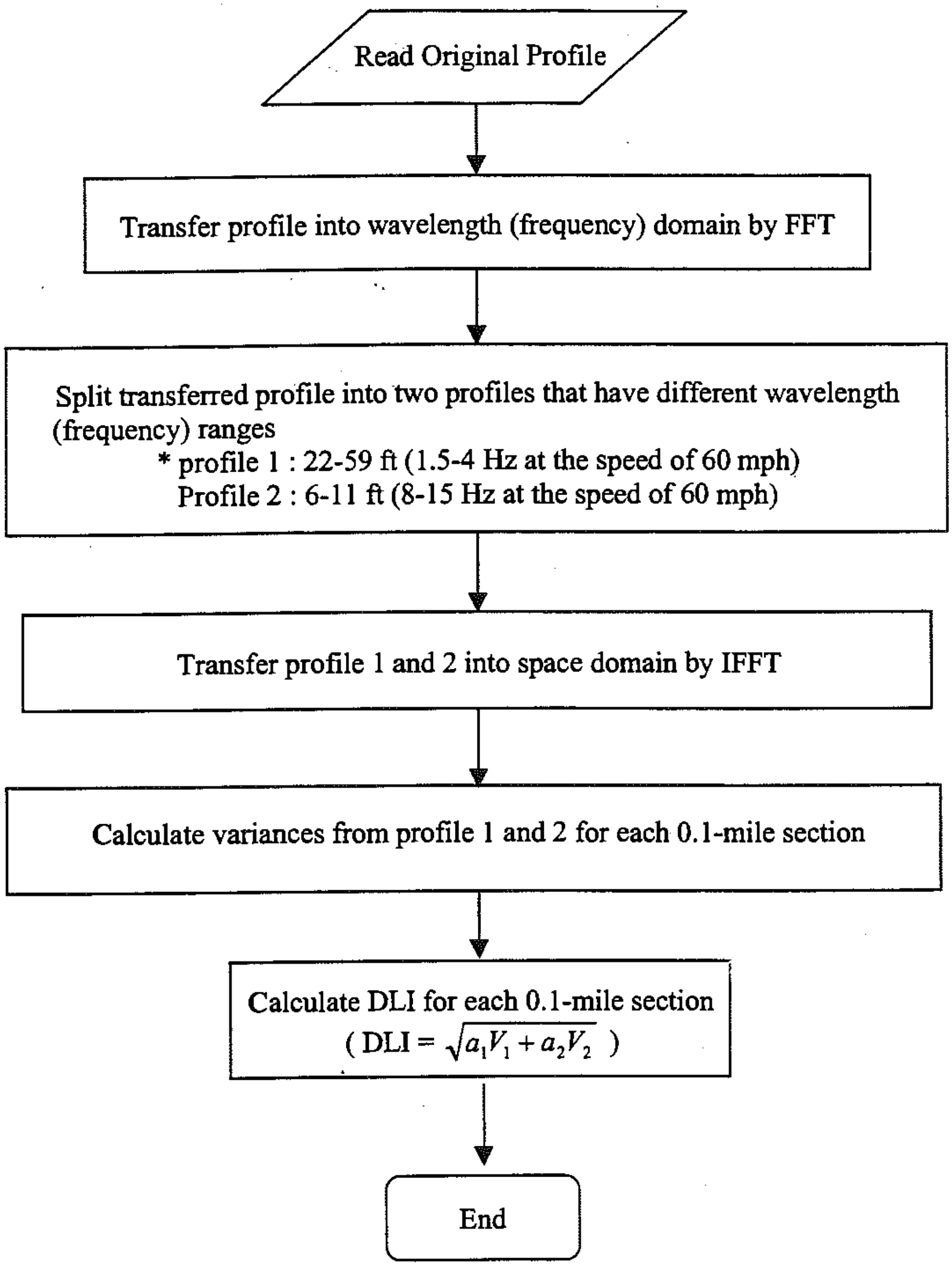
$$DLI = \sqrt{a_1 V_1 + a_2 V_2} \tag{6.4}$$

where V_1 is the variance of elevation of profile 1 (unit: 10^{-2} in);
V_2 is the variance of elevation of profile 2 (unit: 10^{-2} in);
a_1 and a_2 are weighting factors;
Profile 1 contains only waves in the wavelength range of 22 to 59 ft (which corresponds to a frequency range of 1.5-4.0 Hz for a truck traveling at 60 mph);
Profile 2 contains only waves in the wavelength range of 6 to 11 ft (which corresponds to a frequency range of 8.0-15.0 Hz for a truck traveling at 60 mph).

Profiles 1 and 2 are obtained by filtering out the content from all wavelengths of the original profile that has been transformed in the wavenumber domain except for the critical wavelength ranges. This process is done according to the following steps:

- Transform the original profile into the wavenumber domain using the Fast Fourier Transform (FFT) algorithm.
- Split the transformed profile into two profiles that have wavelength ranges of 22 - 59 ft and 6 - 11 ft, respectively. This can be done by forcing zero amplitudes for all wavelengths except for the above critical wavelength ranges.
- Transform the above two profiles back to the space domain using the Inverse FFT (IFFT) algorithm.
- Calculate variances (V_1 and V_2) from both profiles for each 0.1-mile section.
- Calculate DLI for each 0.1-mile section using the above equation.

The flowchart for the above-described process is shown in Figure 6.8. The weighting factor a_1 for V_1 is set equal to one for convenience. The value for the weighting factor, a_2, was determined as that which gives the highest correlation between the DLI and dynamic load.



* Profile 1 (or 2) is made in wavelength domain by making amplitudes zero for all waves except wavelength range of 22 to 59 ft (or 6 to 11 ft).

FIGURE 6.8 Flow Chart for Calculating DLI

6.2.2 Calibration and Verification of the New DLI Index

To see the relationship between the variances of the two filtered profiles (containing the critical wavelengths only) and dynamic load, twenty rigid pavement sections having the same RQI (RQI = 65) but different DLC-values were analyzed. These sections are those used to get the RQI threshold value (Chapter 4), and they have DLC-values ranging from 6.56% (low to no dynamic loading) to 11.32 % (relatively high dynamic loading). This means that the RQI was not able to differentiate between cases of high versus low dynamic loading. On the other hand, based on the above discussion, the variance of the two filtered profiles may differentiate between high and low dynamic loading cases.

Using the filtered profiles, the DLI was calculated for each of the twenty sections using the above equation. Figure 6.9 (a) shows the relationship between DLI and DLC with a weighting factor a_2 of 14 (R^2 = 0.742). The curve for DLI vs. 95th percentile dynamic load is shown in Figure 6.9 (b), with R^2 = 0.839. A linear equation was used to fit the data. The relationships between DLC and DLI have different R^2-values for different weighting factors. In Figure 6.9 (c), R^2-values were plotted against the weighting factor, a_2. The figure shows that a weighting factor of 10.8 gives the highest R^2- value for the DLI-DLC relationship and a weighting factor of 14.0 for the relationship of DLI and 95th percentile dynamic load. Since all twenty sections used for this analysis have the same RQI, the RQI, unlike the DLI, could not differentiate between cases of high versus low dynamic loads for these twenty sections. The same can be said for the International Roughness Index (IRI). This is clearly evidenced by the low R^2-value obtained between DLC and 95th percentile load versus IRI, respectively, as shown in Figure 6.10.

The same analysis described above was done at different RQI-levels (RQI ranging from 35 to 90) and for all pavement types. The corresponding pavement sections were extracted from the same pool of sections used in Chapter 4. Figure 6.11 shows the DLI-DLC plots at constant RQI-values for rigid pavements. The figure shows good correlations for most RQI-levels except for lower RQI-values (RQI=35 and RQI=45). This RQI-level represents a relatively new pavement, with very low DLC-values (DLC less than 8). The pavement surface is essentially smooth, and both RQI and DLI are able to characterize that. Therefore this difference is of no real consequence. Figure 6.12 shows the DLI-DLC plots at constant RQI-values for composite pavements. Again, good correlations exist for high RQI-levels. Figure 6.13 shows the DLI-DLC plots at constant RQI-values for flexible pavements. The figure shows lower R^2-values, indicating higher variability in flexible pavement surfaces.

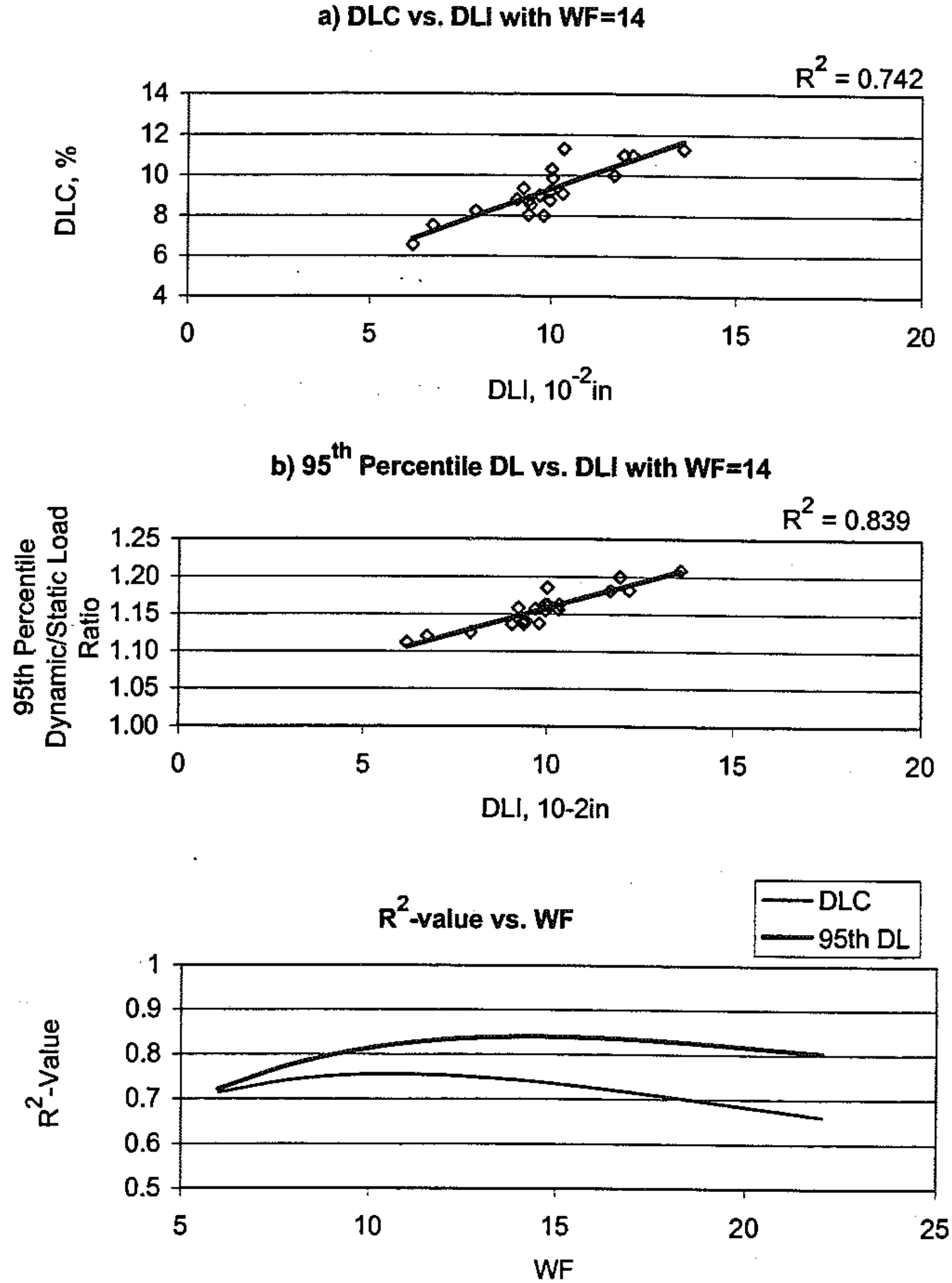


FIGURE 6.9 Relationship between DLI and DLC for 20 Sections Having the Same RQI

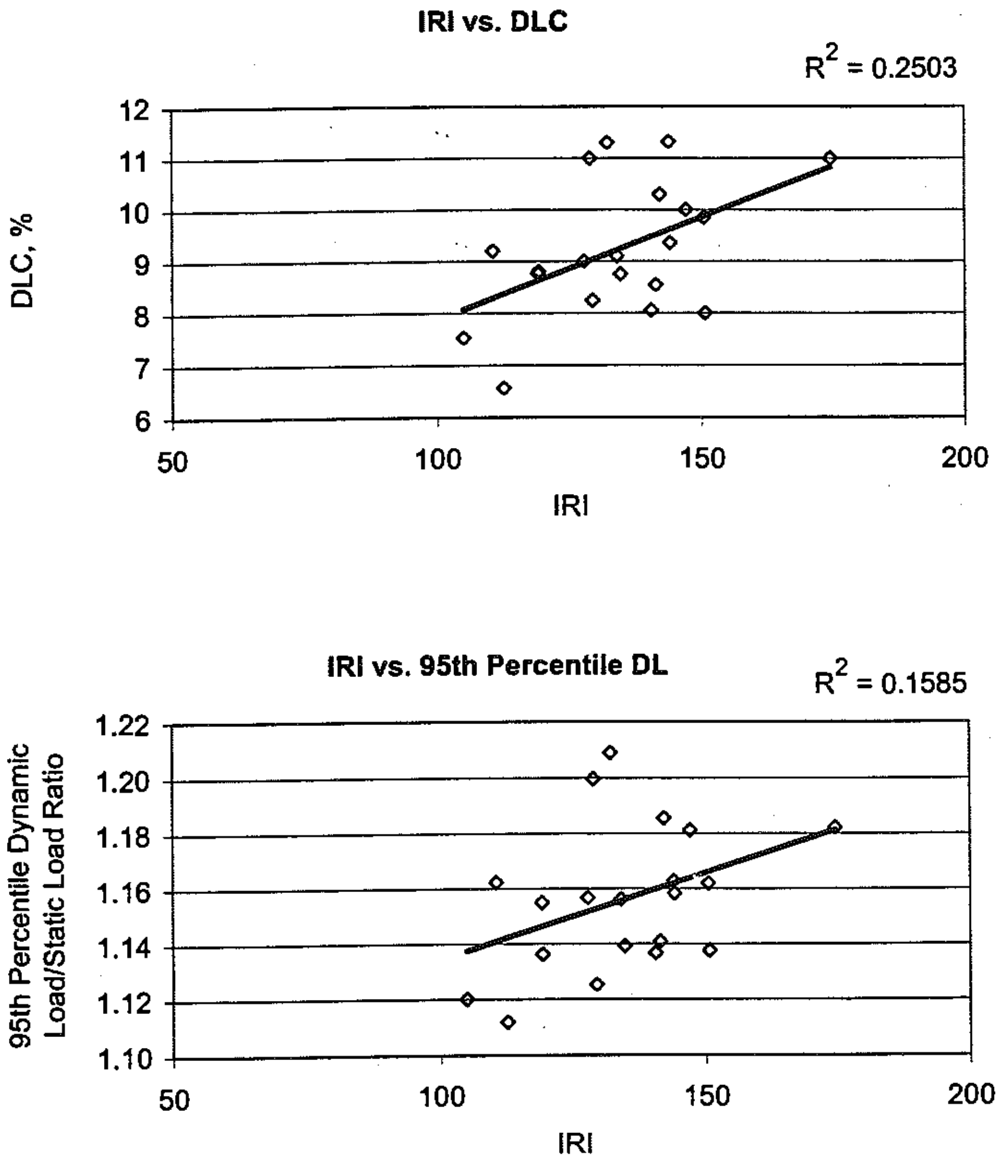


FIGURE 6.10 Relationship between IRI and DLC for 20 Sections Having the Same RQI

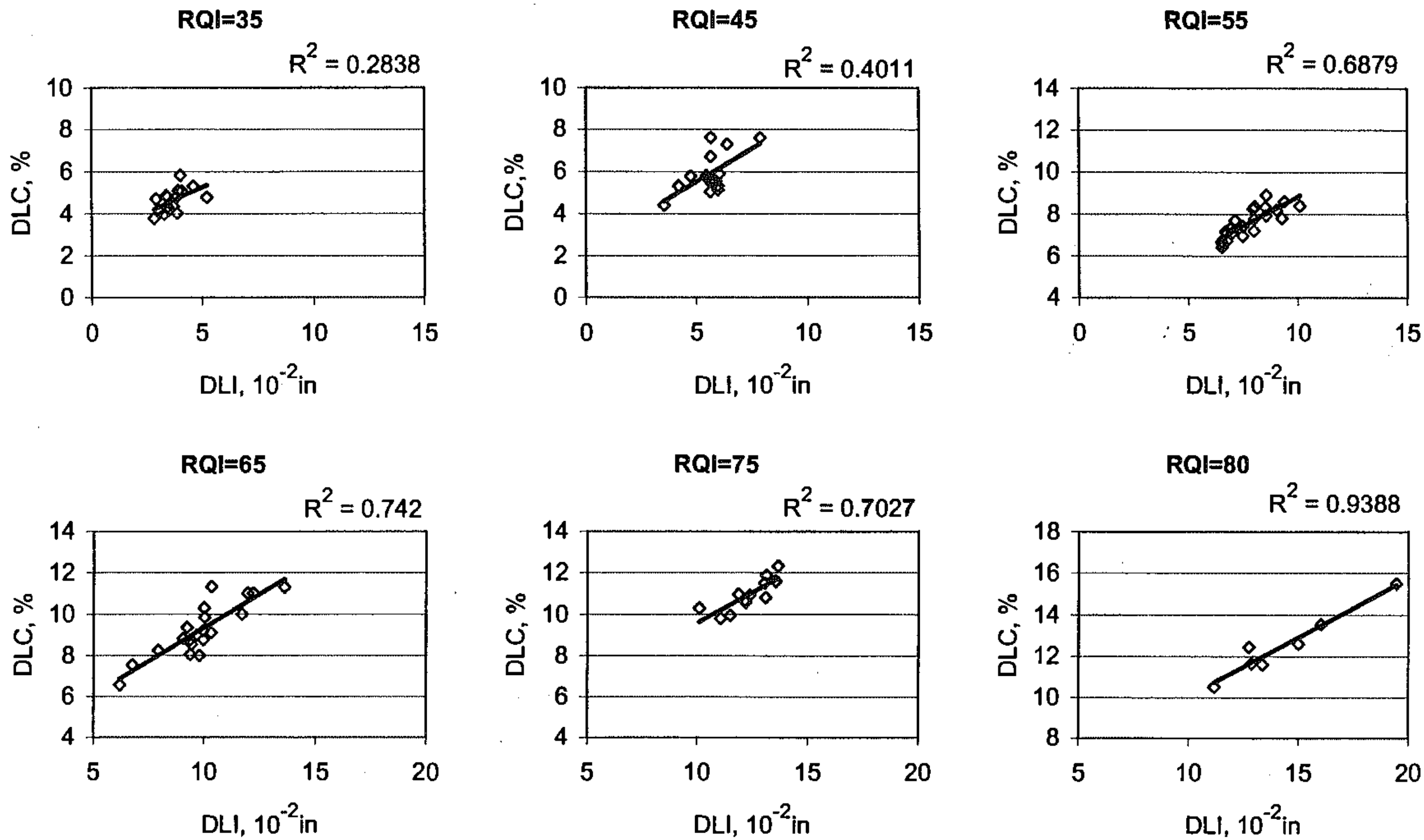


FIGURE 6.11 DLI-DLC Plots at Constant RQI-Values for Rigid Pavements

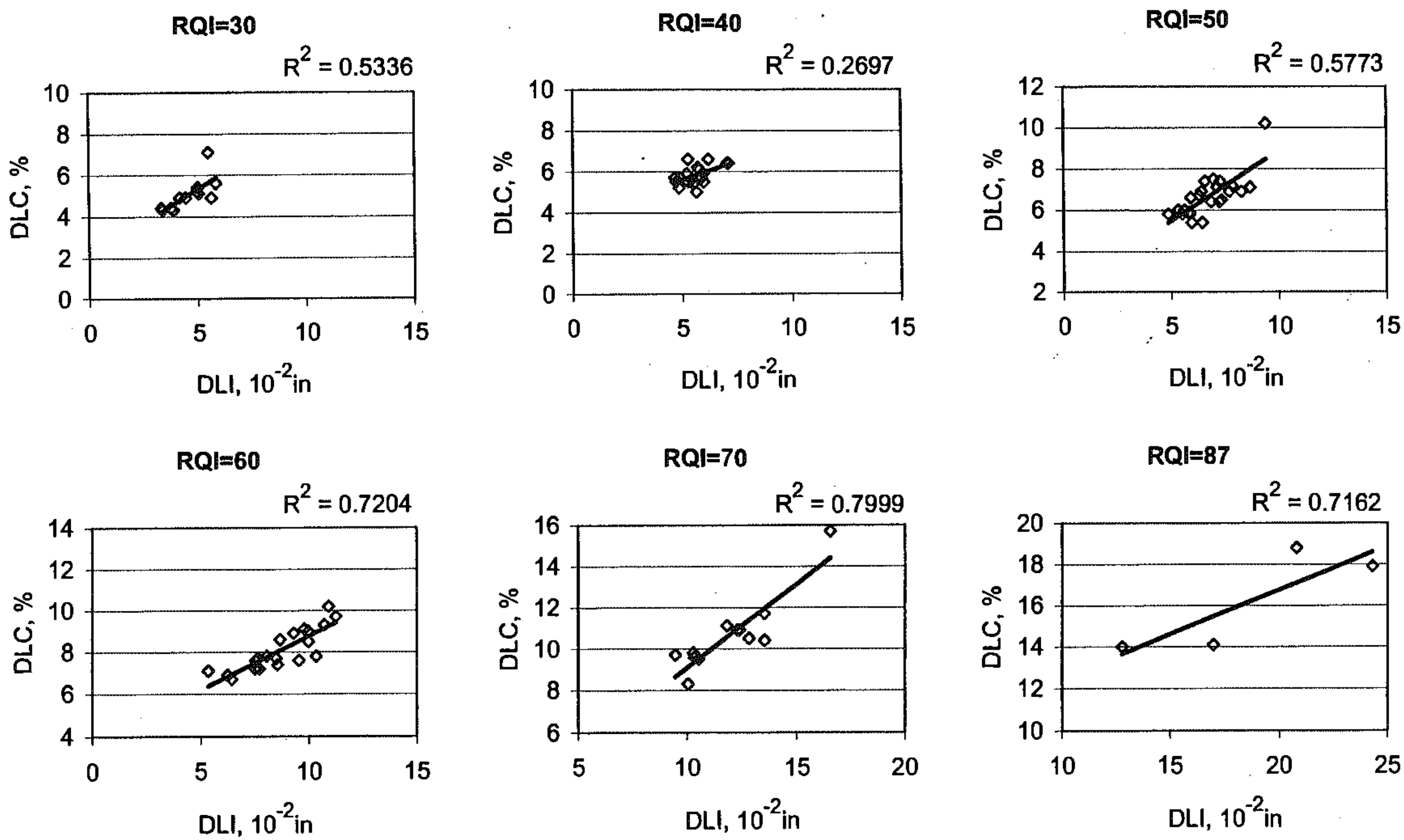


FIGURE 6.12 DLI-DLC Plots at Constant RQI-Values for Composite Pavements

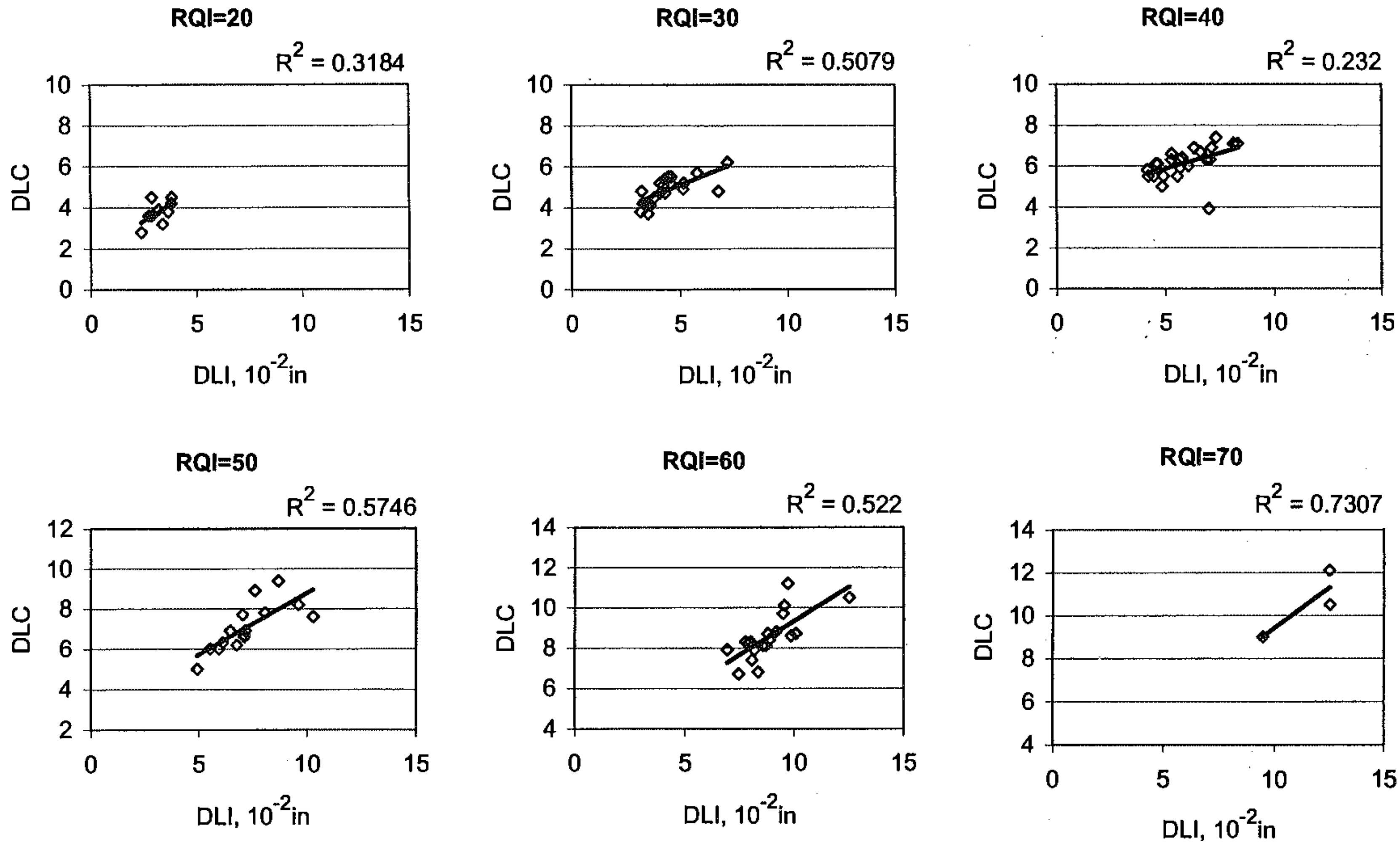


FIGURE 6.13 DLI-DLC Plots at Constant RQI-Values for Flexible Pavements

Next, the overall relationship between DLI and dynamic load was determined for rigid, composite and flexible pavements, respectively. The analysis used all 333 pavement sections from Chapter 4, representing a large range of RQI values. Figures 6.14 (a) and (b) show the variation of DLC and 95th percentile dynamic load, respectively, with DLI for rigid pavements. Figure 6.14 (c) shows R^2-values for different weighting factors. Figures 6.15 and 6.16 show the same things for composite and flexible pavements, respectively. These plots have somewhat higher R^2-values than those using RQI. Based on the R^2-values against weighting factors for each pavement type, a weighting factor of 14 was selected for the DLI equation.

Finally, the overall relationships between DLI and RQI were determined for rigid, composite and flexible pavements, respectively, as shown in Figure 6.17. As expected, these relationships are similar to that between DLC and RQI because DLI is representative of truck dynamic loading.

6.3 CONCLUSION

In conclusion, it can be stated that the DLI is a good indicator of dynamic truck-axle loads. It can differentiate between profiles that generate high dynamic loads and those having the same RQI but generating low dynamic loads. Most importantly, use of the DLI negates the need for running a truck simulation program. This makes it possible to decide whether a particular pavement section with a given surface profile needs smoothing or not based on the DLI-value. Thus the DLI can be used as a project-level roughness index for deciding whether or not to smooth a pavement based on dynamic load considerations.

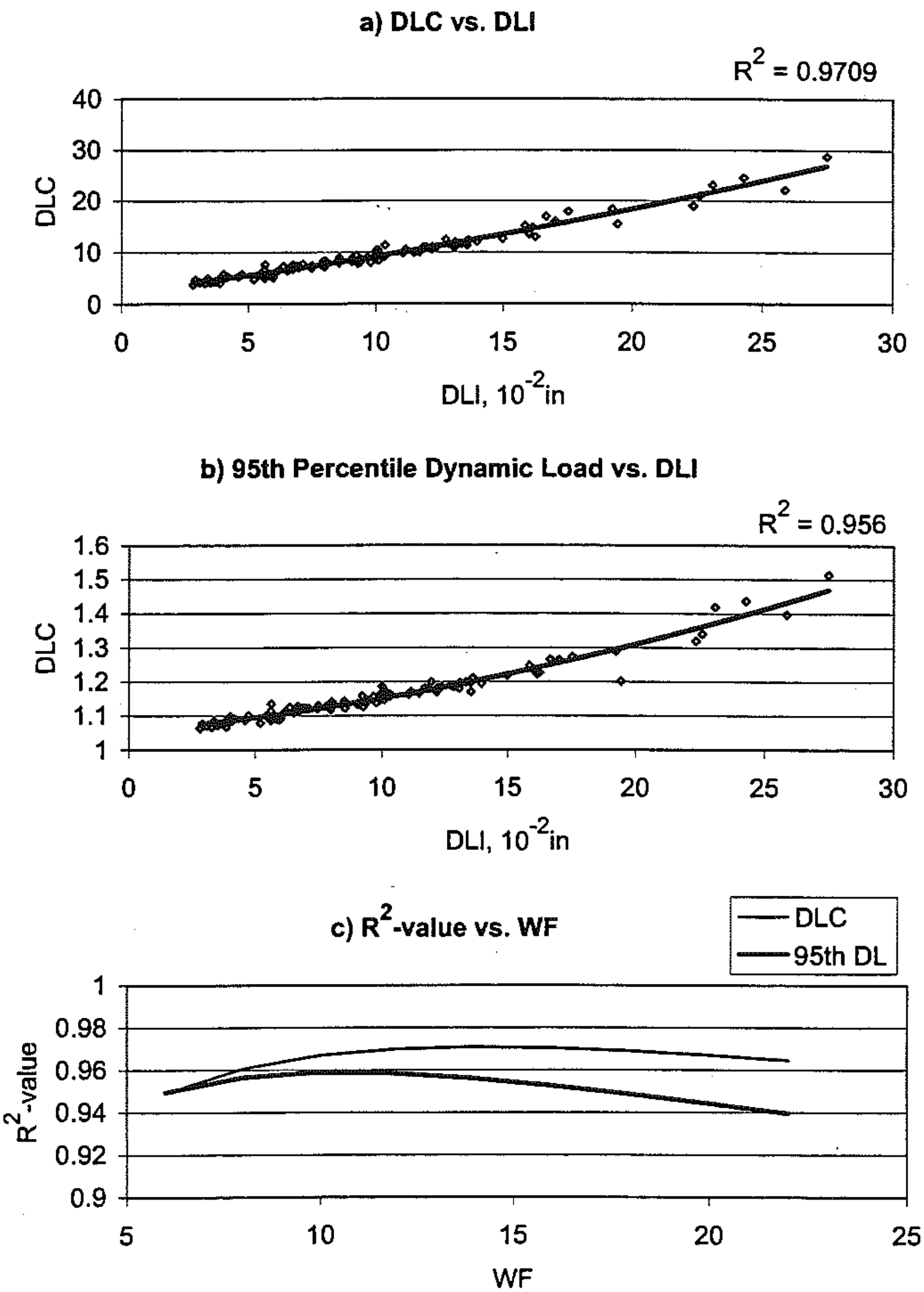


FIGURE 6.14 Dynamic Load vs. DLI for Rigid Pavements (n=109)

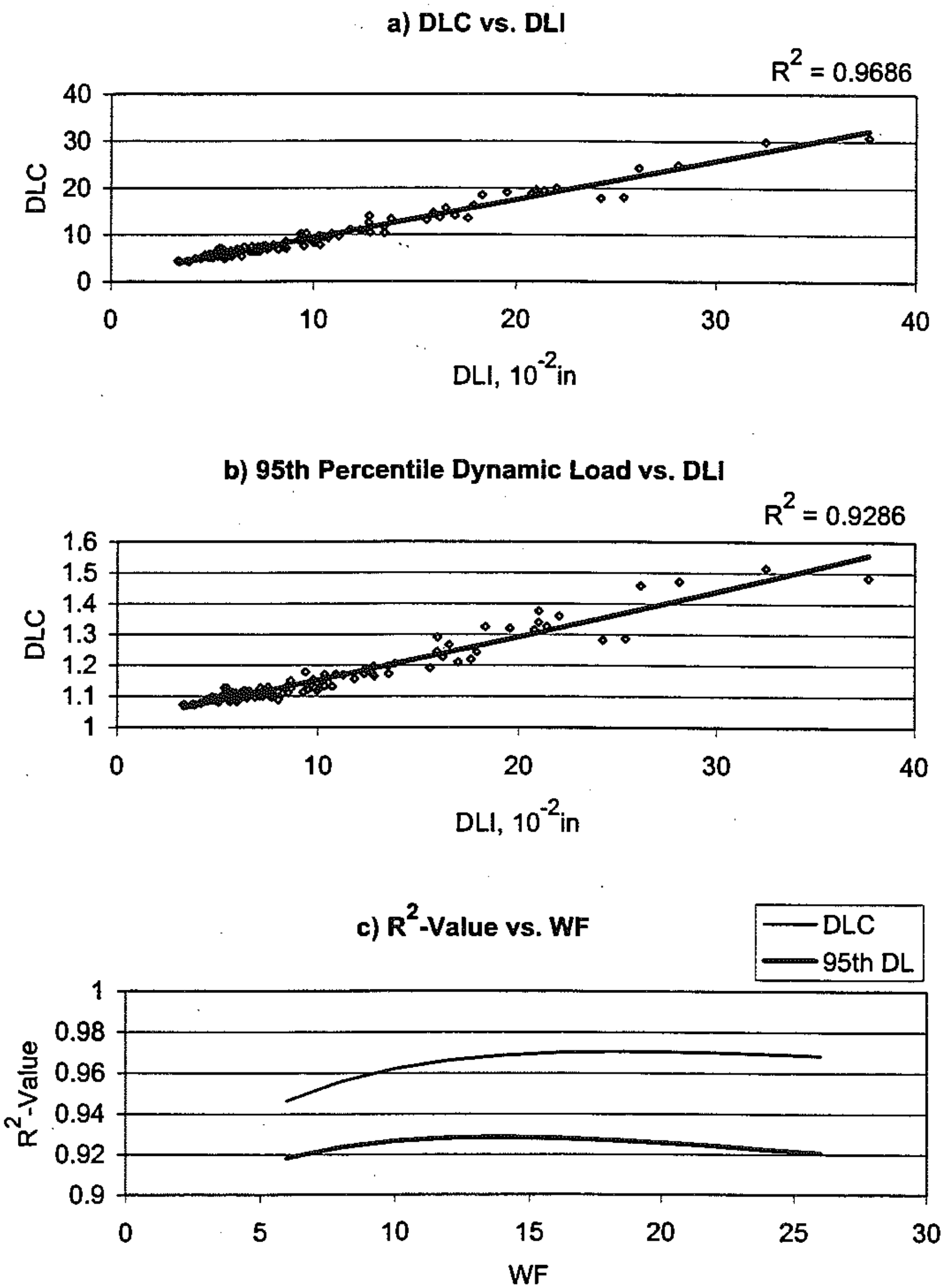


FIGURE 6.15 Dynamic Load vs. DLI for Composite Pavements (n=113)

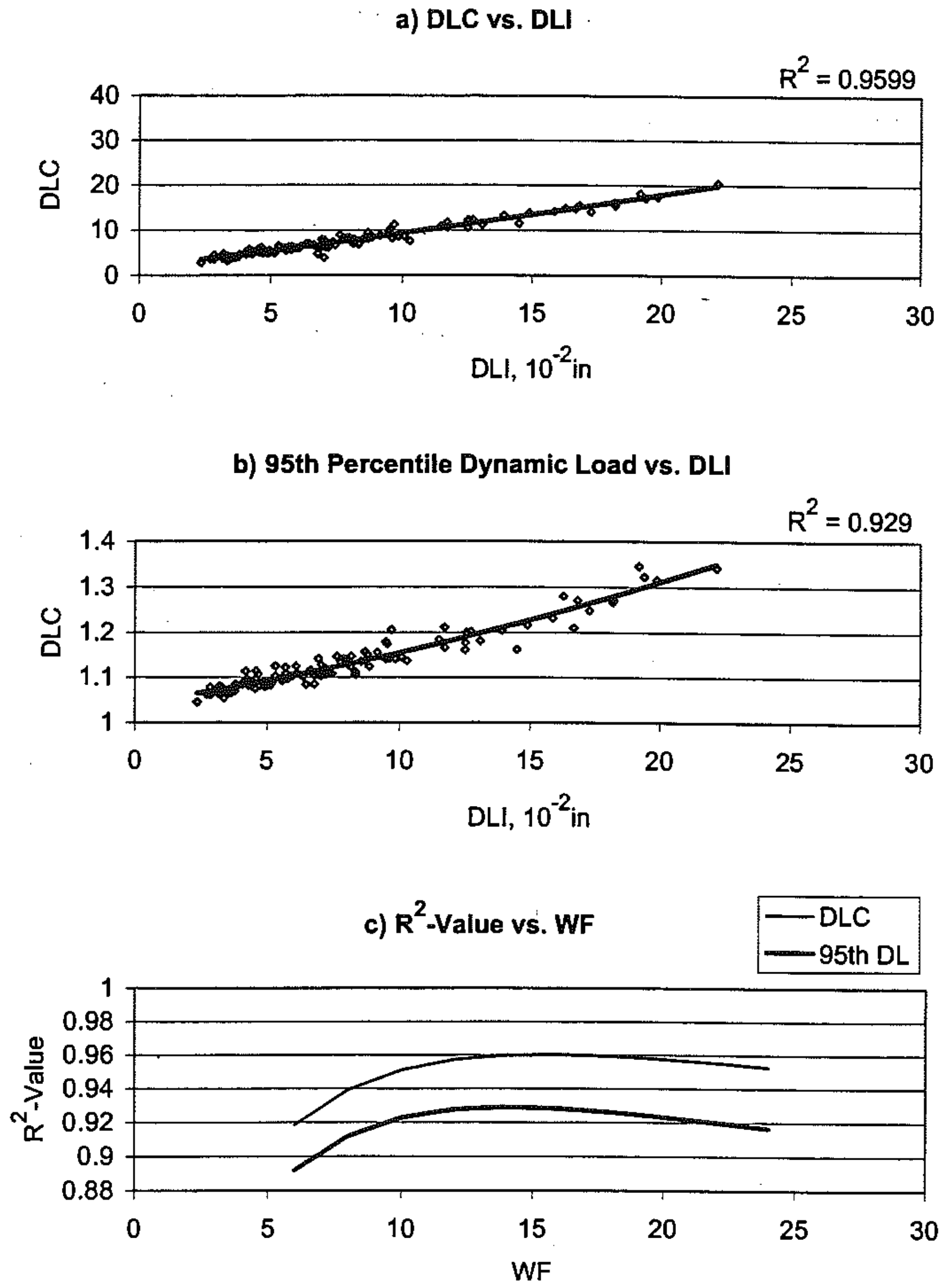


FIGURE 6.16 Dynamic Load vs. DLI for Flexible Pavements (n=111)

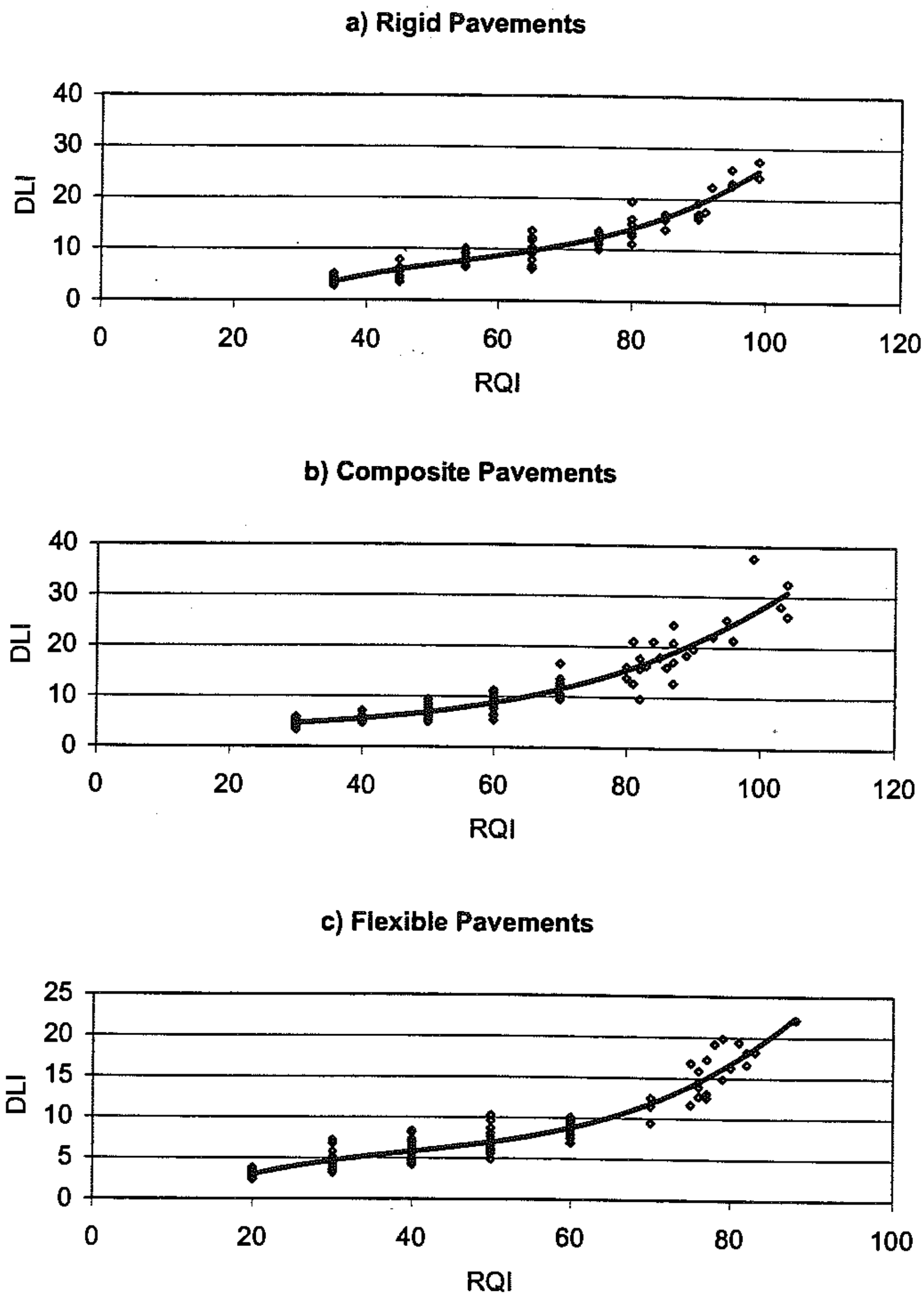


FIGURE 6.17 DLI versus RQI Curve (n=333)

CHAPTER 7
DEVELOPMENT OF PROJECT-LEVEL ROUGHNESS THRESHOLDS FOR PREVENTIVE MAINTENANCE ACTION AIMED AT REDUCING DYNAMIC LOADS

Summary

DLI threshold values and corresponding life extensions were determined using relative damage and reduction in pavement life concepts. Using the 4^{th} power law, relative damages from the 95^{th} percentile dynamic load at different DLI values and the corresponding percent reduction in life were calculated and plotted for 333 sections. Estimates of pavement life extension resulting from smoothing its surface were then generated for different Remaining Service Life (RSL) values. The results were presented in tables showing the expected life extension for a range of RSL- and DLI- values. These tables would enable a highway agency to determine when a particular pavement needs to be smoothed to obtain a given (desired) life extension. The analysis was done for the three pavement types (rigid, flexible and composite).

RSL-values were calculated for 0.5-mile sections from the first data set using actual distress growth over time. The results showed that for rigid pavements, 17% of sections with DLI between 7 and 11 and 51% of sections with DLI between 11 and 15 would have life extensions of more than 3 years. For composite pavements, none of the sections would have life extensions of 3 years or more. For flexible pavements, 9% of sections with DLI between 7 and 11 and 34% of sections with DLI between 11 and 15 would have life extensions of more than 3 years. These results indicate that preventive maintenance smoothing action is best suited for rigid pavements.

7.1 INTRODUCTION

Roughness thresholds aimed at minimizing dynamic loads can play an important role in pavement management and preventive maintenance (PM) program. If a PM action, in the form of smoothing the pavement surface, is taken when the critical roughness level is reached it could extend the service life of the pavement by several years, since it will reduce roughness-generated dynamic loads.

In this chapter, the new roughness index (DLI) described in Chapter 6 is used to develop tables of predicted life extension for pavements with various Remaining Service Life (RSL) values. The analysis was based on mechanistic principles. Dynamic axle loads obtained from the TruckSim™ program were used to calculate the relative damage at different roughness (DLI) levels. The corresponding reduction in pavement life was then used to calculate the life extension that would be achieved, if a PM smoothing action were to be taken, at different RSL-values. These tables can be used to decide on preventive maintenance candidates for smoothing action.

7.2 DEVELOPMENT OF DLI-THRESHOLDS AND CORRESPONDING LIFE EXTENSION

The analysis in this section uses the relationships between dynamic load and DLI that were derived in Chapter 6. The relative dynamic load-induced damage in pavements can be estimated, as explained in Chapter 5, by using a power law:

$$Relative\,Damage = \left(\frac{L_{dynamic}}{L_{static}}\right)^{n} \qquad (7.1)$$

where n is the damage exponent (typically, n = 3-5).

The theoretical percent reduction in pavement life can be calculated as (Miner, 1945):

$$R = Percent\ Reduction\ in\ Pavement\ Life = 100\%\ [1 - (Relative\ Damage)^{-1}] \qquad (7.2)$$

For example, 100% reduction means that one load could fail the pavement. This is a relative value and damage is assumed to follow the 4^{th} power law.

Using the 4^{th} power law, relative damages from the 95^{th} percentile dynamic load at different DLI values, and the corresponding percent reduction in life were calculated and plotted in Figures 7.1, 7.2 and 7.3 for rigid, composite and flexible pavements, respectively.

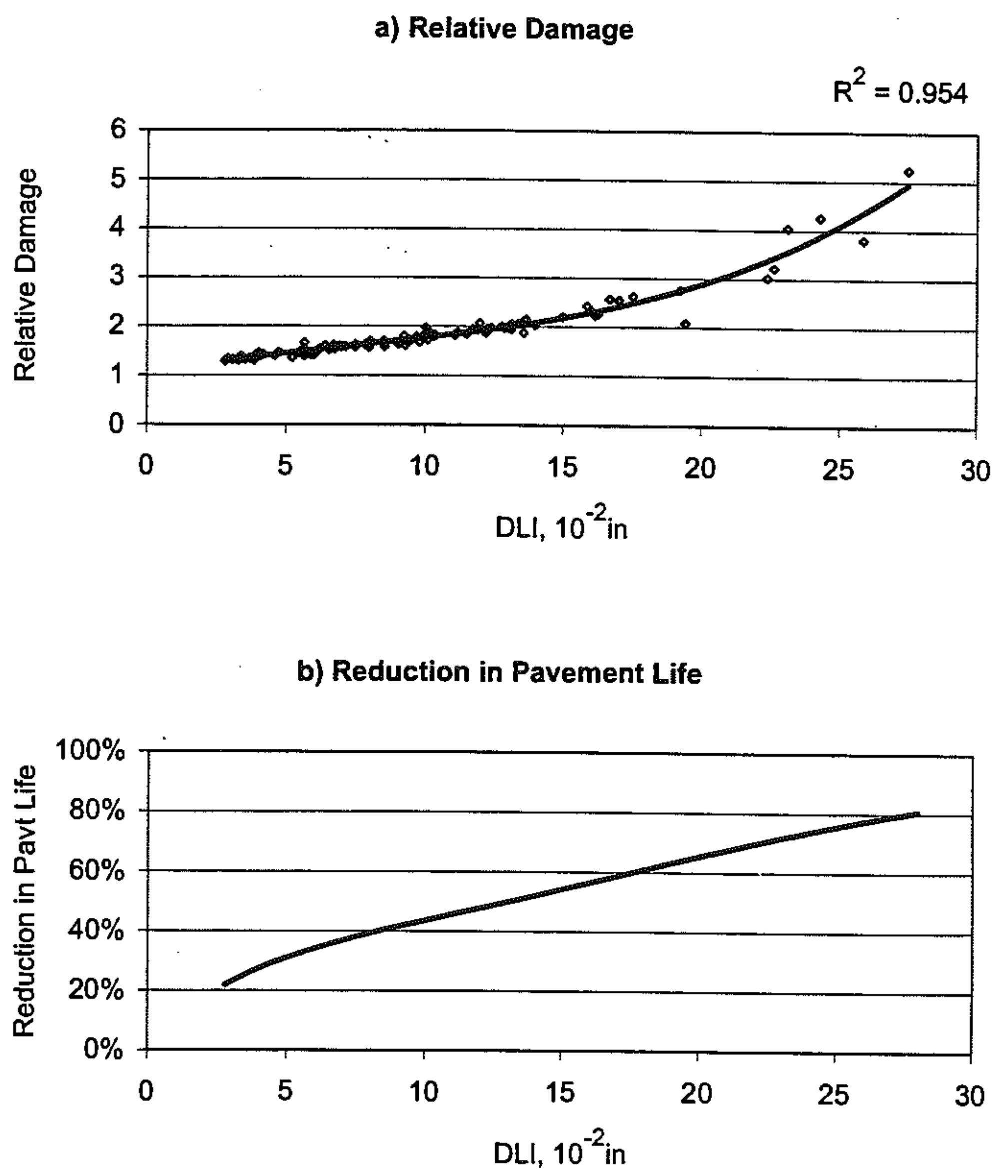


FIGURE 7.1 Relative Damages from the 95th Percentile Dynamic Load at Different DLI for Rigid Pavements (n=109)

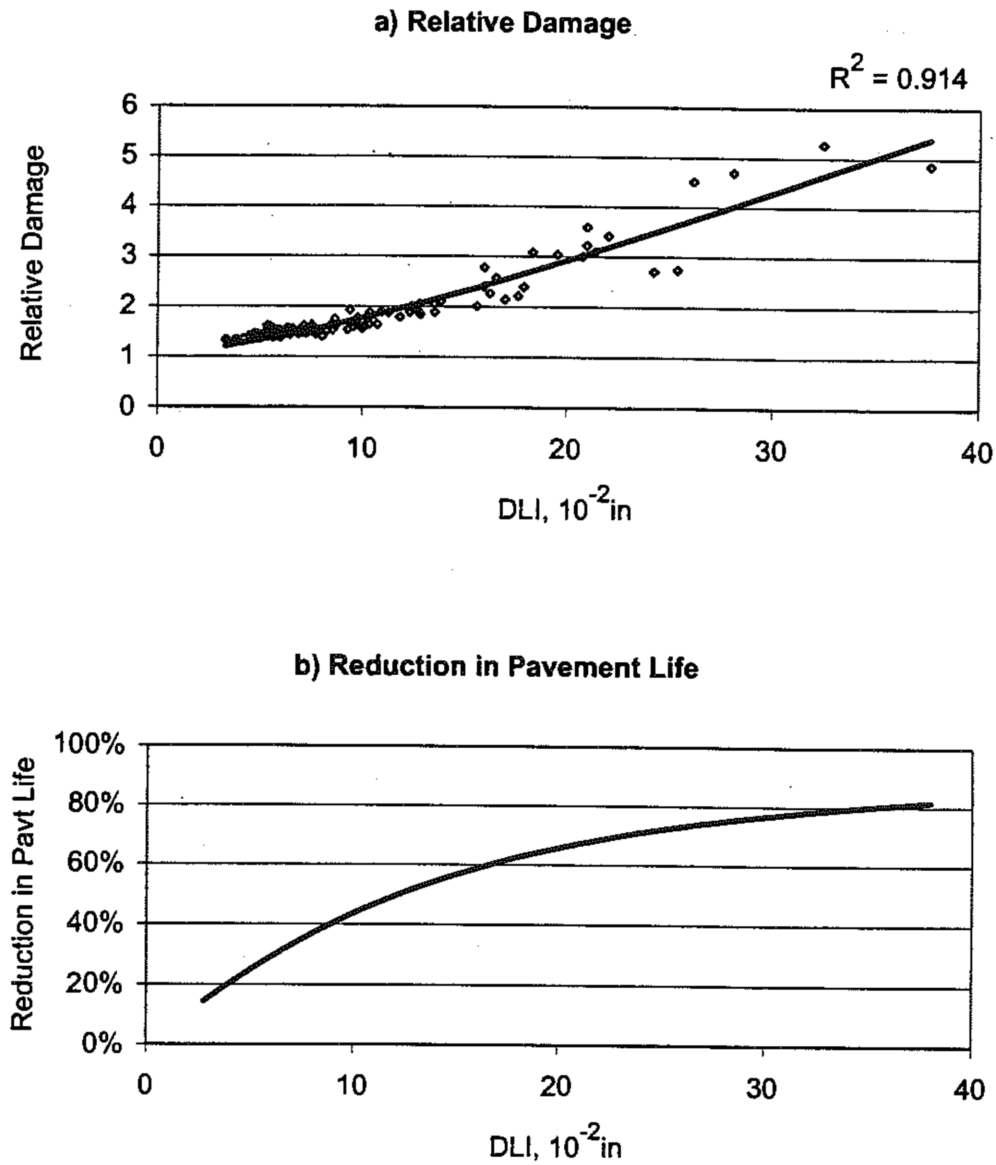
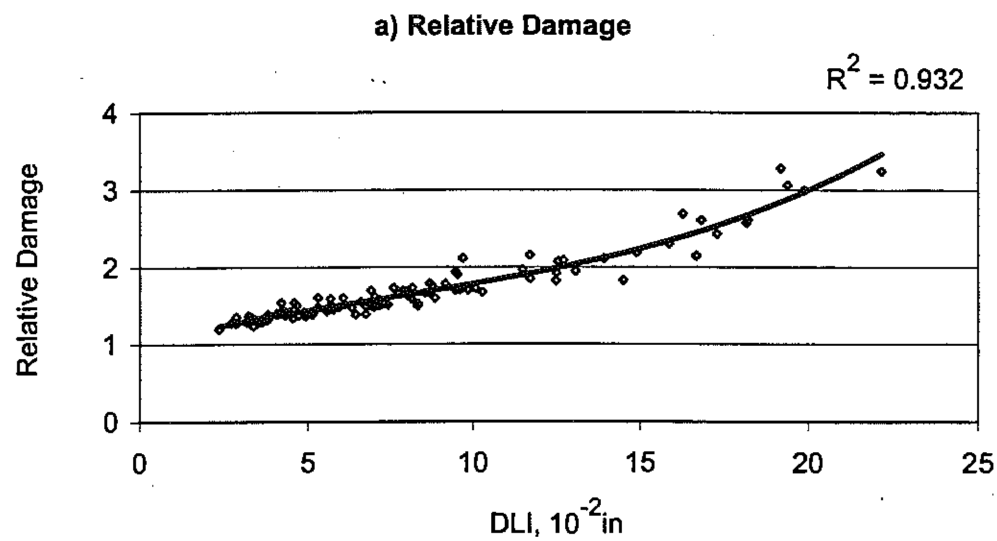


FIGURE 7.2 Relative Damages from the 95th Percentile Dynamic Load at Different DLI for Composite Pavements (n=113)



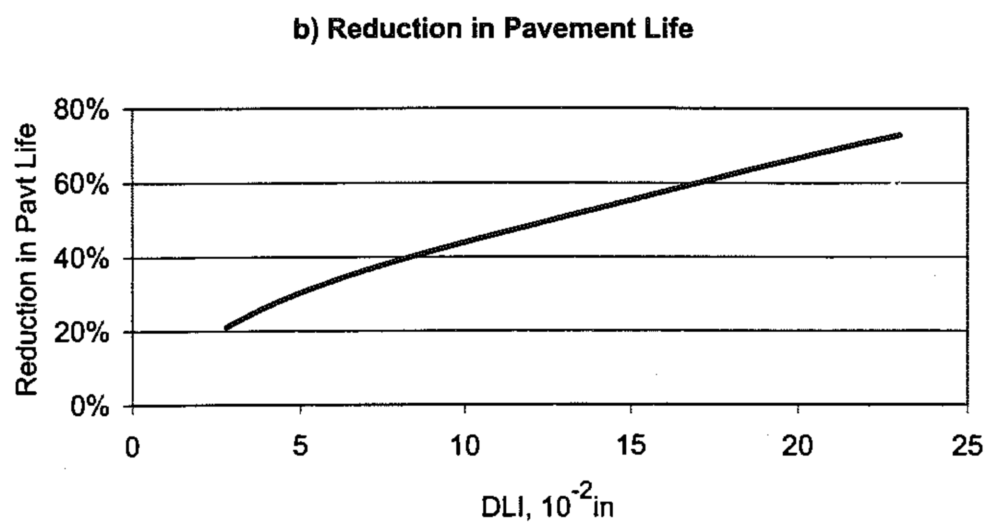


FIGURE 7.3 Relative Damages from the 95th Percentile Dynamic Load at Different DLI for Flexible Pavements (n=111)

The general equation for the curves relating relative damage to DLI can be written as:

$$y = a\,(\text{DLI})^3 + b\,(\text{DLI})^2 + c\,(\text{DLI}) + 1 \tag{7.3}$$

where y is the relative damage and a, b, and c are regression constants.

The corresponding R^2-values were between 0.914 and 0.954, with the higher values being for rigid pavements. Table 7.1 summarizes relevant parameters and R^2-values of the best-fit curves.

TABLE 7.1 Parameters and R^2-Values of Fitting Curves for DLI-Relative Damage Relationship

Pavement Type	a	b	c	R^2
Rigid	2.81E-4	-6.75E-3	1.16E-1	0.954
Composite	-2.52E-5	2.63E-3	5.31E-2	0.914
Flexible	2.67E-4	-5.81E-3	1.09E-1	0.932

The life extension that can be achieved by smoothing a pavement section of a given remaining service life can be determined as:

$$\text{Life extension} = (R\text{-}R_0)\ \text{RSL} \tag{7.4}$$

where R corresponds to the reduction in life at the current DLI value;
R_0 corresponds to the reduction in life at the DLI value after the smoothing action.

The analysis was done for rigid, flexible and composite pavements with RSL values ranging from 20 to 6 years. For the calculation of life extension, the DLI value corresponding to a pavement condition immediately after the smoothing action was determined to be 3 based on Figures 6.14, 6.15 and 6.16. The following example shows how to calculate life extension for given RSL and DLI values. The calculation of the life extension expected from smoothing a rigid pavement surface that has an RSL of 14 years and a DLI of 10 is as follows:

From Figure 7.1 (b), R-value corresponding to DLI of 10 is 43.6%,
and, R_0-value corresponding to DLI of 3 is 21.9%.

Thus, Life extension = (0.436-0.219)×14 = 3.0 years

Tables 7.2 through 7.4 show the life extension that can be expected for a range of RSL- and DLI- values. If a minimum life extension of 3 years were to be adopted, then the shaded areas within each table would represent conditions where smoothing PM action is warranted. Note that the life extension calculations are based on a DLI-value of 3 (and not zero) after the smoothing action, since no pavement is perfectly smooth. This should translate in more realistic estimates shown in the tables. Also note that while the tables give life extension predictions of all possible combinations of RSL and DLI values, the combinations of high RSL and DLI values are less likely to occur in practice.

7.3 EFFECT OF VARIABILITY IN THE RELATIONSHIP BETWEEN ROUGHNESS AND DYNAMIC LOAD ON THE PREDICTION OF LIFE EXTENSION

While the DLI has a better relationship with dynamic load as compared to RQI, there is some variability in the data. There is a range of dynamic loads that can be generated at a given DLI. To investigate the effect of this variability on the prediction of life extension, a probability analysis was done on the cases corresponding to a target life extension of three years. These cases would correspond to the minimum allowed life extension for effective preventive maintenance by smoothing action, and they constitute the upper envelope of the shaded area in Tables 7.2, 7.3 and 7.4. From the relationship between DLI and relative damage (see Figures 7.1, 7.2 and 7.3), the residual error for the regression curve was calculated for the DLI ranges of interest (i.e., minimum life extension of 3 years). The results are shown in Table 7.5. Note that these results should be on the conservative side because the range of DLI for which the residual error is calculated is beyond the most likely range for optimal PM smoothing, and the error increases with increasing DLI. Using the calculated SE values, the ranges of predicted life extensions corresponding to 80%, 60% and 40% confidence levels were calculated. These correspond to 90%, 80% and 70% reliability levels for the minimum value of life extension.

The same analysis was done for the RQI. The residual error in relative damage was calculated from Figures 5.4, 5.5 and 5.6 for the three pavement types. The results and corresponding RQI ranges are shown in Table 7.6.

TABLE 7.2 Life Extension for Different RSL and DLI-values for Rigid Pavements

DLI	RSL														
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
5.0	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.6	1.7	1.8
6.0	0.7	0.9	1.0	1.1	1.2	1.3	1.5	1.6	1.7	1.8	2.0	2.1	2.2	2.3	2.4
7.0	0.9	1.0	1.2	1.3	1.5	1.6	1.8	1.9	2.1	2.2	2.4	2.5	2.7	2.8	3.0
8.0	1.0	1.2	1.4	1.6	1.7	1.9	2.1	2.3	2.4	2.6	2.8	2.9	3.1	3.3	3.5
9.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.5	2.7	2.9	3.1	3.3	3.5	3.7	3.9
10.0	1.3	1.5	1.7	2.0	2.2	2.4	2.6	2.8	3.0	3.3	3.5	3.7	3.9	4.1	4.3
11.0	1.4	1.7	1.9	2.1	2.4	2.6	2.9	3.1	3.3	3.6	3.8	4.0	4.3	4.5	4.8
12.0	1.6	1.8	2.1	2.3	2.6	2.8	3.1	3.4	3.6	3.9	4.1	4.4	4.7	4.9	5.2
13.0	1.7	2.0	2.2	2.5	2.8	3.1	3.4	3.6	3.9	4.2	4.5	4.8	5.0	5.3	5.6
14.0	1.8	2.1	2.4	2.7	3.0	3.3	3.6	3.9	4.2	4.5	4.8	5.1	5.4	5.7	6.0
15.0	1.9	2.3	2.6	2.9	3.2	3.6	3.9	4.2	4.5	4.8	5.2	5.5	5.8	6.1	6.5
16.0	2.1	2.4	2.8	3.1	3.5	3.8	4.1	4.5	4.8	5.2	5.5	5.9	6.2	6.6	6.9
17.0	2.2	2.6	2.9	3.3	3.7	4.0	4.4	4.8	5.1	5.5	5.9	6.2	6.6	7.0	7.4
18.0	2.3	2.7	3.1	3.5	3.9	4.3	4.7	5.1	5.5	5.9	6.2	6.6	7.0	7.4	7.8
19.0	2.5	2.9	3.3	3.7	4.1	4.5	5.0	5.4	5.8	6.2	6.6	7.0	7.4	7.8	8.3
20.0	2.6	3.0	3.5	3.9	4.4	4.8	5.2	5.7	6.1	6.5	7.0	7.4	7.8	8.3	8.7

TABLE 7.3 Life Extension for Different RSL and DLI-values for Composite Pavements

DLI	RSL														
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
5.0	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	2.0	2.1
6.0	0.9	1.0	1.2	1.3	1.5	1.6	1.7	1.9	2.0	2.2	2.3	2.5	2.6	2.8	2.9
7.0	1.1	1.3	1.5	1.7	1.9	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.3	3.5	3.7
8.0	1.3	1.6	1.8	2.0	2.2	2.5	2.7	2.9	3.1	3.3	3.6	3.8	4.0	4.2	4.5
9.0	1.5	1.8	2.1	2.3	2.6	2.8	3.1	3.4	3.6	3.9	4.1	4.4	4.6	4.9	5.2
10.0	1.7	2.0	2.3	2.6	2.9	3.2	3.5	3.8	4.1	4.4	4.6	4.9	5.2	5.5	5.8
11.0	1.9	2.2	2.6	2.9	3.2	3.5	3.8	4.2	4.5	4.8	5.1	5.5	5.8	6.1	6.4
12.0	2.1	2.4	2.8	3.1	3.5	3.8	4.2	4.5	4.9	5.2	5.6	5.9	6.3	6.6	7.0
13.0	2.2	2.6	3.0	3.4	3.7	4.1	4.5	4.9	5.2	5.6	6.0	6.4	6.7	7.1	7.5
14.0	2.4	2.8	3.2	3.6	4.0	4.4	4.8	5.2	5.6	6.0	6.4	6.8	7.2	7.6	8.0
15.0	2.5	3.0	3.4	3.8	4.2	4.6	5.1	5.5	5.9	6.3	6.7	7.2	7.6	8.0	8.4
16.0	2.7	3.1	3.5	4.0	4.4	4.9	5.3	5.8	6.2	6.6	7.1	7.5	8.0	8.4	8.8
17.0	2.8	3.2	3.7	4.2	4.6	5.1	5.5	6.0	6.5	6.9	7.4	7.9	8.3	8.8	9.2
18.0	2.9	3.4	3.8	4.3	4.8	5.3	5.8	6.2	6.7	7.2	7.7	8.2	8.6	9.1	9.6
19.0	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	7.9	8.4	8.9	9.4	9.9
20.0	3.1	3.6	4.1	4.6	5.1	5.6	6.1	6.7	7.2	7.7	8.2	8.7	9.2	9.7	10.2

TABLE 7.4 Life Extension for Different RSL and DLI-values for Flexible Pavements

DLI	RSL														
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
5.0	0.6	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
6.0	0.8	0.9	1.0	1.1	1.3	1.4	1.5	1.6	1.8	1.9	2.0	2.1	2.3	2.4	2.5
7.0	0.9	1.1	1.2	1.4	1.5	1.7	1.8	2.0	2.2	2.3	2.5	2.6	2.8	2.9	3.1
8.0	1.1	1.3	1.4	1.6	1.8	2.0	2.2	2.3	2.5	2.7	2.9	3.1	3.2	3.4	3.6
9.0	1.2	1.4	1.6	1.8	2.0	2.2	2.5	2.7	2.9	3.1	3.3	3.5	3.7	3.9	4.1
10.0	1.4	1.6	1.8	2.1	2.3	2.5	2.7	3.0	3.2	3.4	3.6	3.9	4.1	4.3	4.6
11.0	1.5	1.8	2.0	2.3	2.5	2.8	3.0	3.3	3.5	3.8	4.0	4.3	4.5	4.8	5.0
12.0	1.6	1.9	2.2	2.5	2.7	3.0	3.3	3.6	3.8	4.1	4.4	4.7	4.9	5.2	5.5
13.0	1.8	2.1	2.4	2.7	3.0	3.3	3.6	3.9	4.2	4.4	4.7	5.0	5.3	5.6	5.9
14.0	1.9	2.2	2.6	2.9	3.2	3.5	3.8	4.2	4.5	4.8	5.1	5.4	5.7	6.1	6.4
15.0	2.1	2.4	2.7	3.1	3.4	3.8	4.1	4.5	4.8	5.1	5.5	5.8	6.2	6.5	6.8
16.0	2.2	2.6	2.9	3.3	3.7	4.0	4.4	4.8	5.1	5.5	5.8	6.2	6.6	6.9	7.3
17.0	2.3	2.7	3.1	3.5	3.9	4.3	4.7	5.1	5.4	5.8	6.2	6.6	7.0	7.4	7.8
18.0	2.5	2.9	3.3	3.7	4.1	4.5	4.9	5.3	5.8	6.2	6.6	7.0	7.4	7.8	8.2
19.0	2.6	3.0	3.5	3.9	4.3	4.8	5.2	5.6	6.1	6.5	6.9	7.4	7.8	8.2	8.7
20.0	2.7	3.2	3.7	4.1	4.6	5.0	5.5	5.9	6.4	6.8	7.3	7.8	8.2	8.7	9.1

TABLE 7.5 Standard Error in the Relationship between DLI and Relative Damage

Pavement Type	Residual Error	DLI Range for Residual Error
Rigid	0.081	7 to 20
Composite	0.187	7 to 19
Flexible	0.145	7 to 19

TABLE 7.6 Standard Error in the Relationship between RQI and Relative Damage

Pavement Type	Residual Error	RQI Range for Residual Error
Rigid	0.168	50 to 90
Composite	0.277	50 to 85
Flexible	0.239	50 to 85

The final results showing the variation in predicted life extension are shown in Figures 7.4, 7.5 and 7.6 for rigid, composite and flexible pavements, respectively. The figures show that the range in predicted life extension increases with increasing RSL. The figures also show that predictions based on DLI lead to a more narrow range than those based on RQI. Introducing the new roughness index, DLI, reduced the error in the prediction of life extension by about half for rigid pavements. For the other pavement types, the error is reduced by one third. For example, for a RSL of 12 years and a confidence level of 80%, the error in life extension prediction for rigid pavements is ± 0.3 years based on DLI as compared to ± 0.7 years based on RQI. Note also that for both RQI and DLI, rigid pavements exhibit the smallest error ranges, followed by flexible, then composite pavements.

7.4. DISTRIBUTION OF PAVEMENT REMAINING SERVICE LIFE AT DIFFERENT DLI VALUES

Determining the remaining service life (RSL) of pavement sections at different roughness levels is important since it allows for determining the applicability of the life extension tables (derived in Section 7.2) in the context of the current MDOT pavement management system used its capital preventive maintenance program.

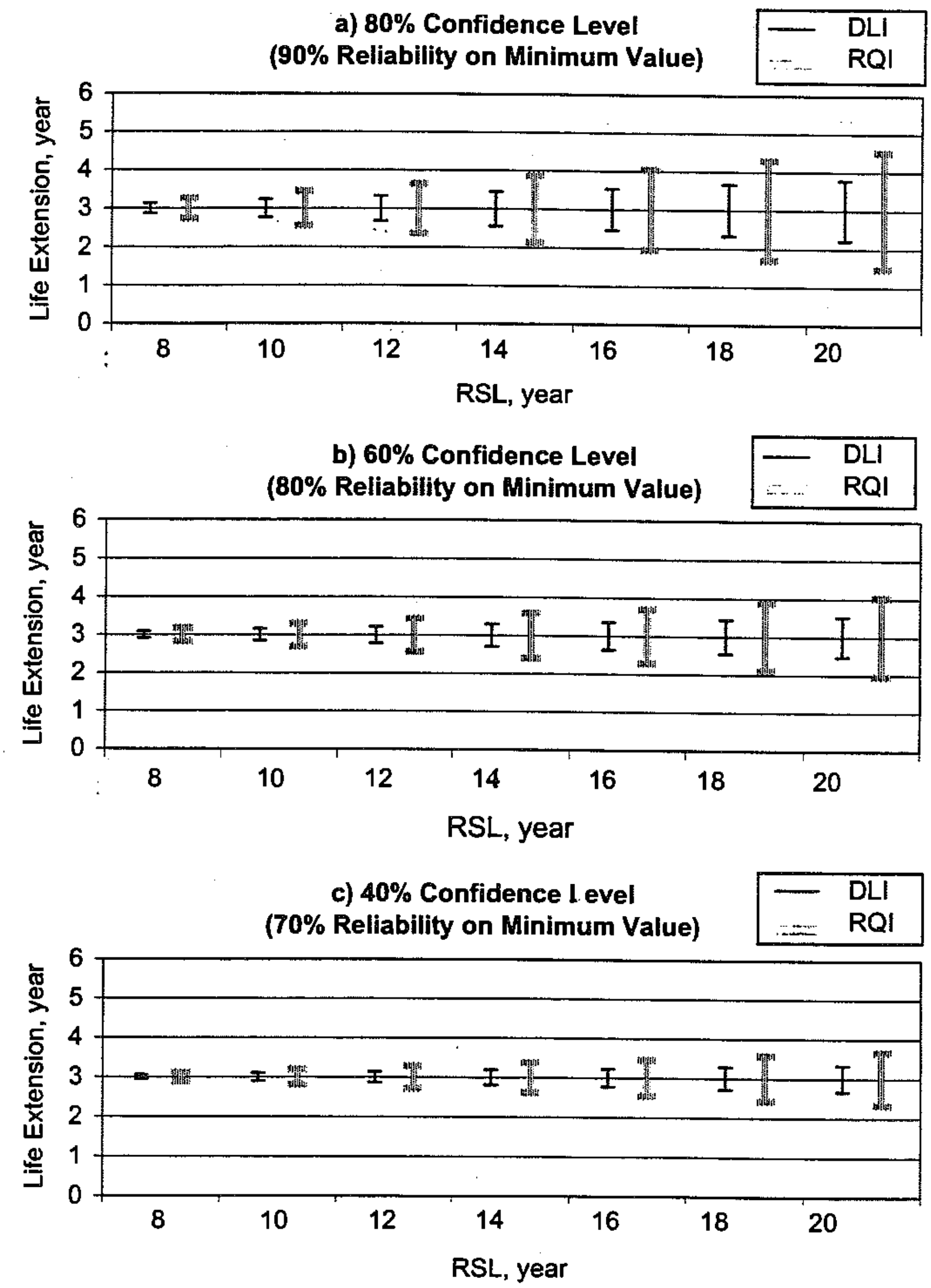


FIGURE 7.4 Range of Possible Life Extension for Rigid Pavements

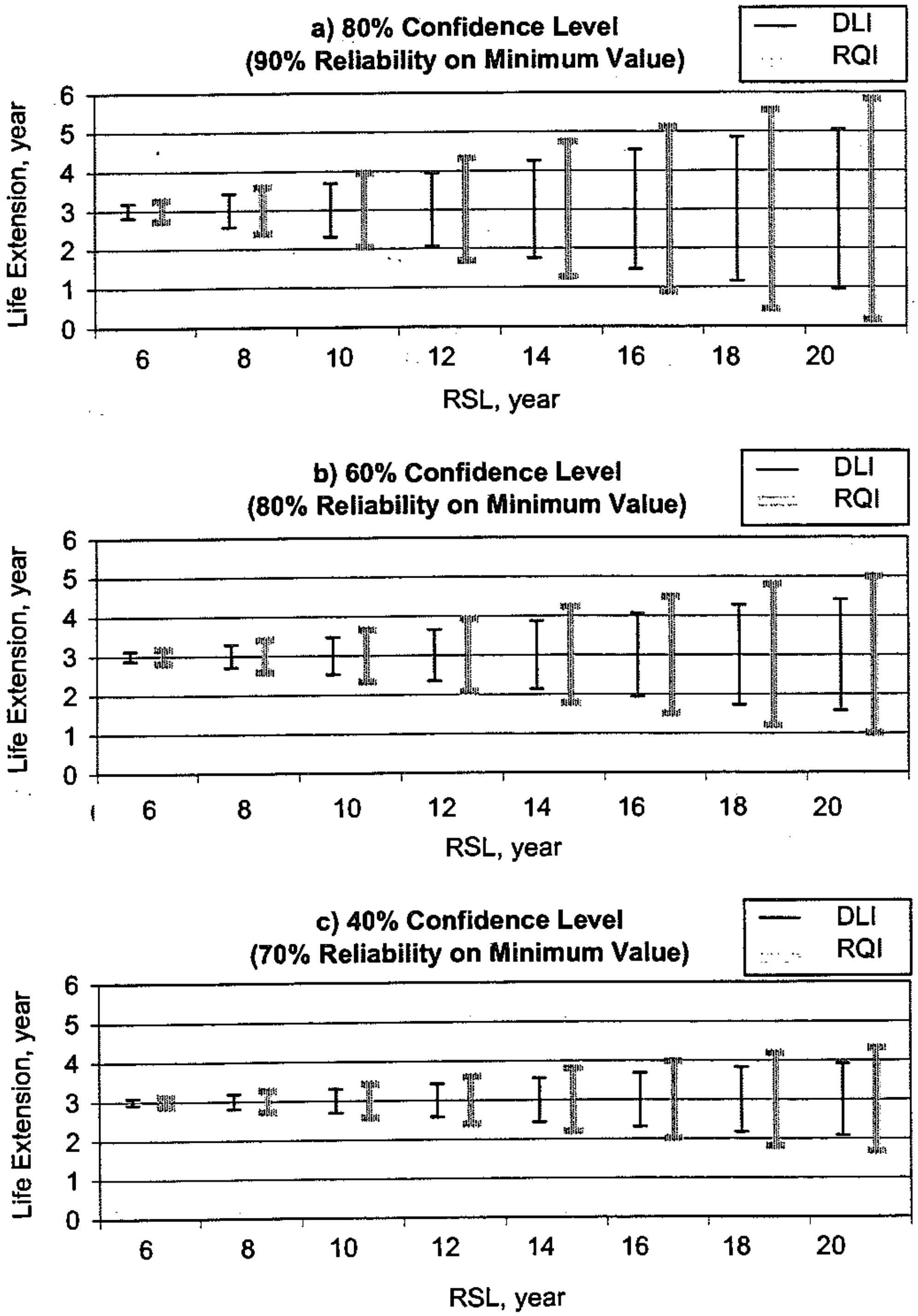


FIGURE 7.5 Range of Possible Life Extension for Composite Pavements

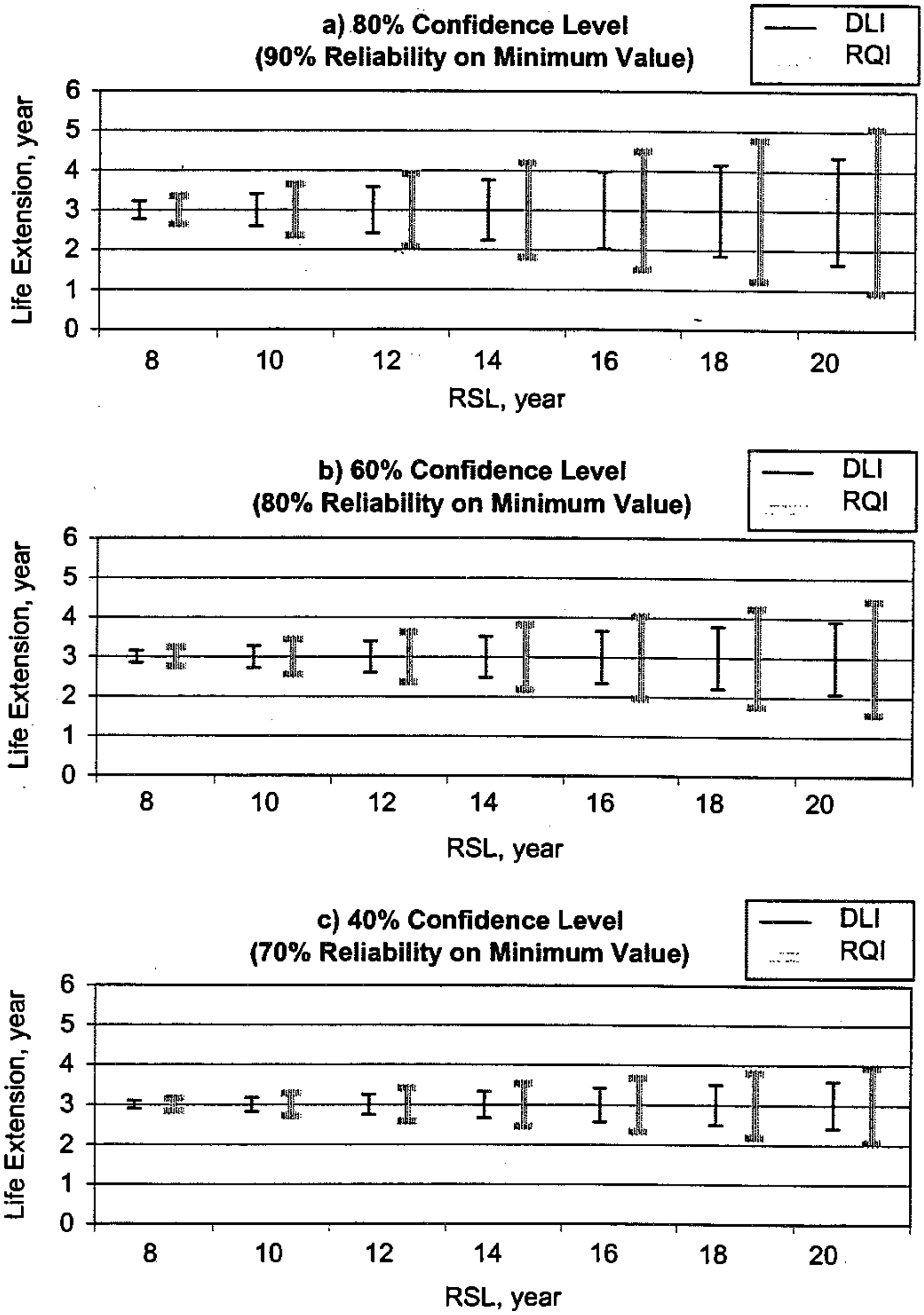


FIGURE 7.6 Range of Possible Life Extension for Flexible Pavements

Superimposing the predicted RSL-values from actual pavement performance on the life extension tables allows for determining the proportion of pavement sections that would be favorable candidates for PM smoothing action, i.e., those with a minimum RSL value to get the desired life extension of 3 years or more. For example, a rigid pavement section with a DLI of 10 needs to have a minimum RSL of 14 to yield a life extension of 3 years or more upon smoothing. The proportion of rigid pavement sections with DLI of 10 having RSL-values greater than 14 would determine the usefulness (applicability) of any PM smoothing action.

The first data set was used for this analysis. Remaining service lives were calculated for those 0.5-mile pavement sections that have DLI greater than 7. This was done using the DI prediction model developed by MDOT. This model uses a logistic function having the following form,

$$DI(t) = \frac{(a+b)a}{a + b \times \exp(-rt)} - a \qquad (7.5)$$

where, t = age, and a, b and r are regression parameters.

Figure 7.7 illustrates how to calculate the RSL given past DI-values. The RSL is defined by MDOT as the number of years needed to reach the threshold DI-value of 50, from the current DI-value. RSL distributions for pavement sections that have DLI-values between 7 and 11, and between 11 and 15 are shown in Figures 7.8, 7.9 and 7.10 for the three pavement types. The number of sections with a DLI greater than 15 was too small to show a reliable distribution of RSL-values.

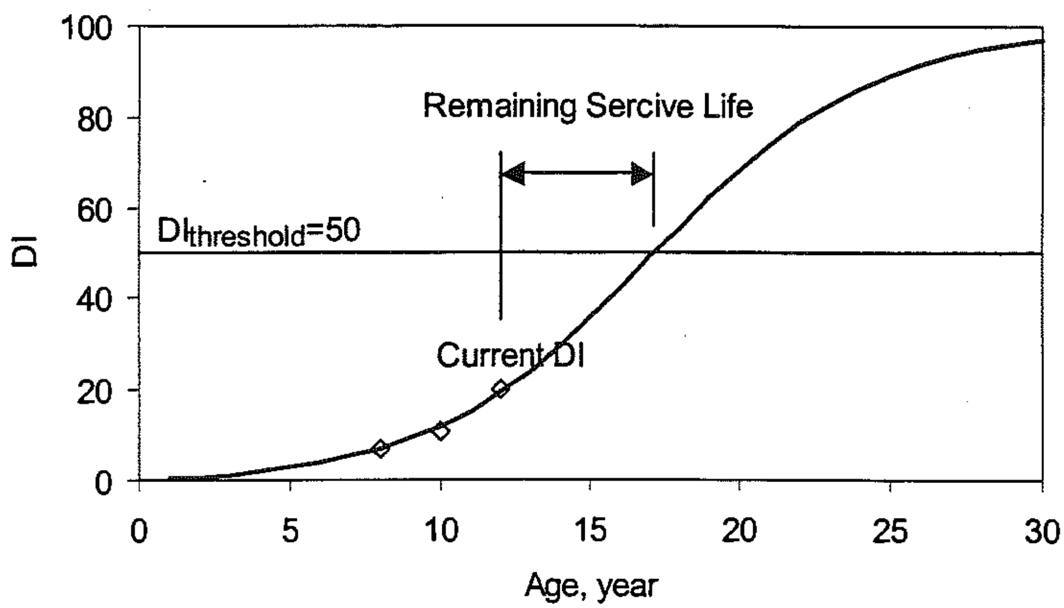
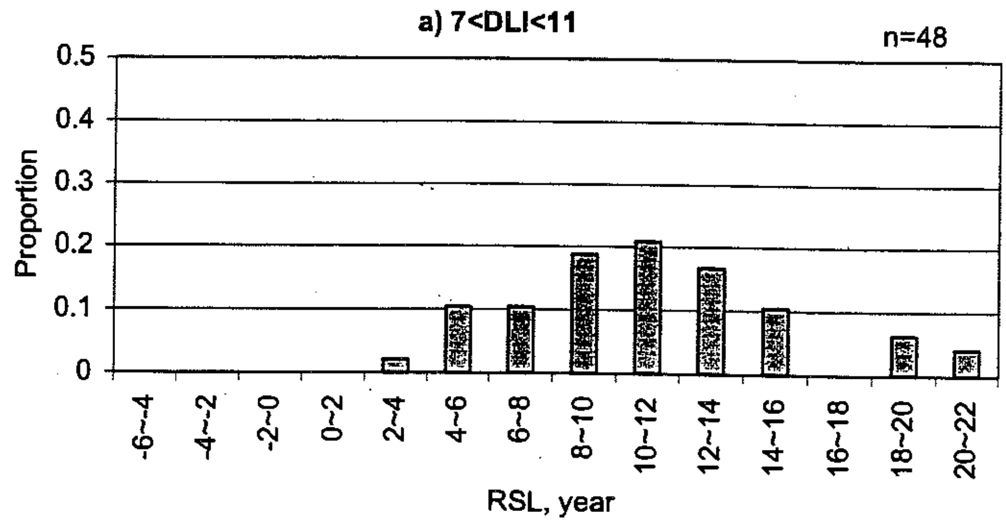


Figure 7.7 Illustration of Remaining Service Life Calculation



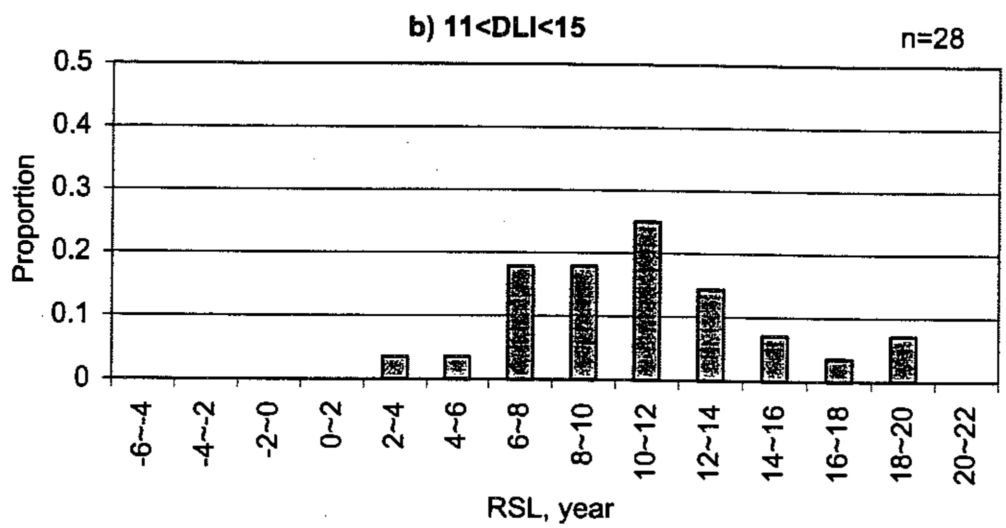


FIGURE 7.8 Remaining Service Life Distributions for Rigid Pavements

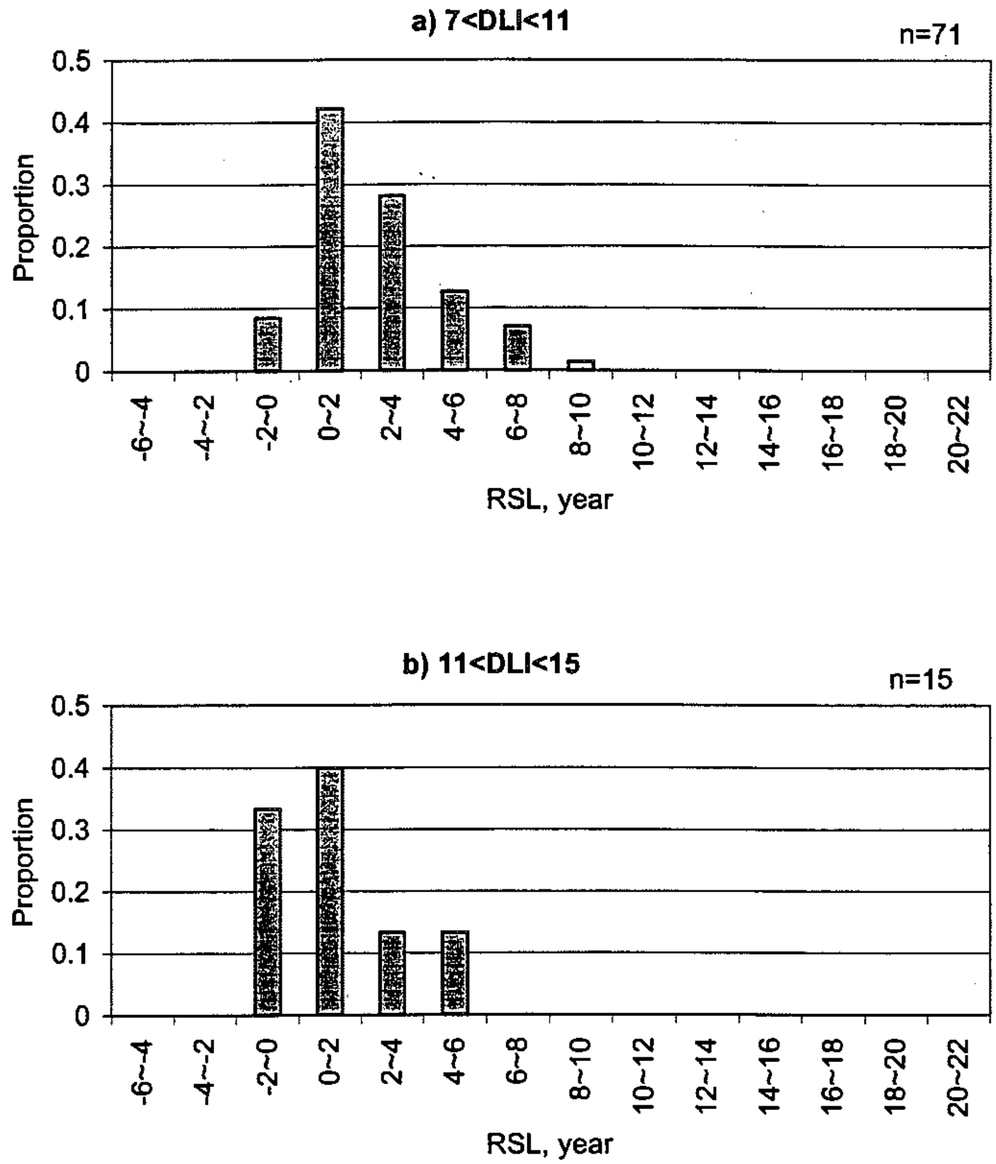
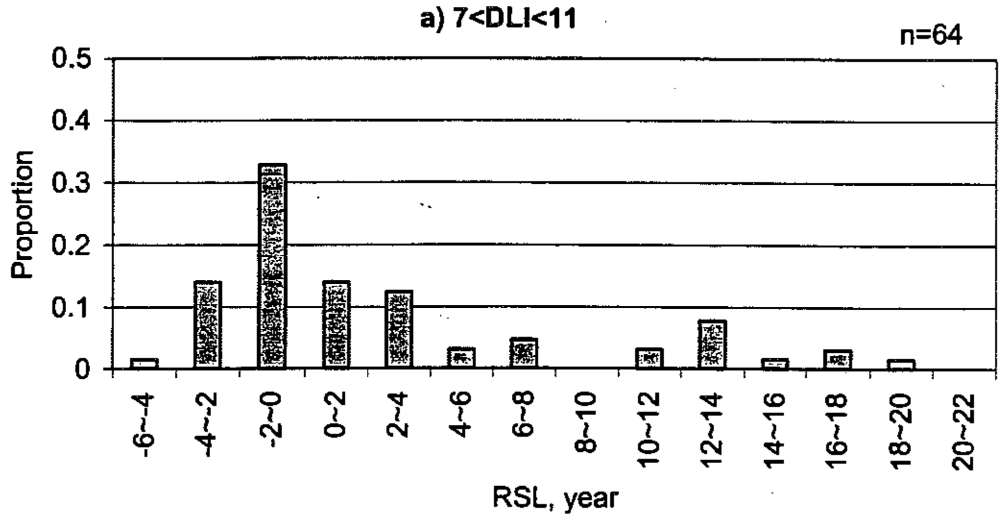


FIGURE 7.9 Remaining Service Life Distributions for Composite Pavements



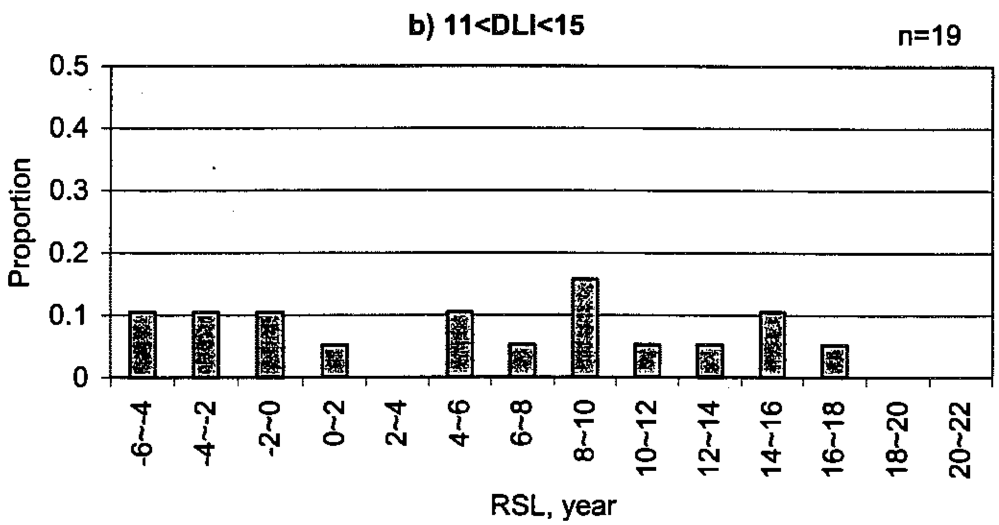


FIGURE 7.10 Remaining Service Life Distributions for Flexible Pavements

7.4.1 Rigid Pavements

It can be seen that rigid pavements have the largest RSL-values. All pavement sections analyzed have positive RSL-values. About 29% of the rigid pavement sections that have DLI-values ranging from 7 to 11 have RSL-values greater than 13 years. According to Table 7.2, about 60% of these sections (17% of all rigid pavement sections with a DLI between 7 and 11) would have life extensions of more than 3 years if they were to be smoothed. On the other hand, 57% of the pavement sections with DLI-values ranging from 11 to 15 have RSL-values greater than 10 years, and about 89% of these sections (51% of all rigid pavement sections with DLI-values between 11 and 15) would have life extensions of more than 3 years, i.e., they would be PM candidates.

7.4.2 Composite Pavements

According to Figure 7.8, about 92% of composite pavement sections with DLIs-values ranging from 7 to 11 have positive RSL-values, as compared to 67% with DLI-values ranging from 11 to 15. However, none of these pavement sections have RSL-values corresponding to a life extension of 3 years or more, as can be seen in Table 7.3. The maximum RSL for pavements with a DLI between 7 and 11 is 9 years, which corresponds to a maximum life extension of 2.9 years. For pavement sections with a DLI between 11 and 15, the maximum RSL is 6 years, which corresponds to a life extension of 2.5 years.

7.4.3 Flexible Pavements

For flexible pavements, more sections have negative RSL-values in the above DLI ranges. According to Figure 7.10, about 48% of sections with DLI-values ranging from 7 to 11 and 32% with DLI-values ranging from 11 to 15 have negative RSL-values. This means that these pavements sections already reached the DI threshold (RSL=0) before they reach the roughness level at which smoothing action would be needed. About 14% of pavement sections with a DLI between 7 to 11 have RSL-values greater than 12 years. From Table 7.4, about 62% of these sections (9% of all flexible pavement sections with a DLI between 7 and 11) would have life extension of 3 years or more. For flexible pavements with a DLI between 11 and 15, about 39% of pavement sections have RSL-values greater than 9 years. Table 7.4 shows that 88% of these sections (34% of all flexible pavements with a DLI between 11 and 15) would have life extensions of 3 years or more, i.e., they would be PM candidates for smoothing action.

Based on the results of this analysis, it can be stated that the preventive maintenance action in the form of smoothing surface is most applicable to rigid pavements in terms of life extension gain. Under the current MDOT DI system, it would appear that such smoothing actions may not be as useful for flexible and composite pavements.

7.5 DETERMINING OPTIMAL TIMING FOR SMOOTHING PREVENTIVE MAINTENANCE ACTION

Roughness thresholds aimed at minimizing dynamic loads can play an important role in pavement management and the preventive maintenance (PM) program. If a PM action, in the form of smoothing the pavement surface, is taken when the DLI threshold is reached it can extend the service life of the pavement by several years, since it will reduce roughness-generated dynamic loads.

The ability to predict DLI growth with time is necessary in order to accurately predict the optimum timing for the preventive maintenance action. Ideally, it would be desired to have the ability to predict future DLI-values given a current DLI. This would enable the Maintenance Division within MDOT to plan roughness-related PM actions a few years prior to the pavement reaching the DLI threshold-value. In this section, a reliability-based model for selecting the optimal timing (or planning period) for such preventive maintenance action is proposed using the new DLI-threshold and actual DLI-growth rates from in-service pavements. A similar approach using RQI growth with time is described in detail in Appendix C.

7.5.1 Remaining Smooth Period

In order to implement a preventive maintenance strategy using the roughness threshold concept developed in this study, it is useful to define a "trigger" value equal to:

$$DLI_{trigger} = DLI_{threshold} - \Delta DLI$$

where $DLI_{trigger}$ represents the trigger-value for planning the smoothing PM action some years down the road.

The time (in years) corresponding to ΔDLI can be called the *PM Planning Period (PMP)*. On the other hand, the number of years left to reach the DLI threshold, given the current DLI-value is the *Remaining Smooth Period (RSP)*. The RSP is by definition greater than or equal to the PMP. At the trigger DLI-value, the RSP becomes the PMP. Figure 7.11 illustrates this concept.

7.5.2 Reliability Analysis for DLI Trigger Value

In order to successfully plan for such PM-actions, it is necessary to have a reliable prediction of DLI growth with time. A useful way to interpret the DLI growth data is to use the actual growth rates from each individual pavement section and develop the probability distribution of the DLI growth rate. These results can then be used to calculate the reliability of the PM planning period, PMP, for different $DLI_{trigger}$-values.

Figure C.9 in Appendix C shows such plots for the RQI growth rate for 1382 (805-m or 0.5-mile) sections from 112 rigid pavement projects. This figure shows probability distributions of RQI growth rate for 1, 2, 3 and 4 years. The same analysis can be done for the DLI. The results can be used to calculate the reliability that the pavement will not reach the threshold DLI-value before *x* years for different $DLI_{trigger}$-values, with *x* being the PM planning period. An example of such table for the RQI is shown in Table C.1 in Appendix C. The reliability should decrease with increasing PM planning period and increasing $DLI_{trigger}$-value. Similar tables can be developed for isolating potentially important factors such as traffic volume or pavement thickness.

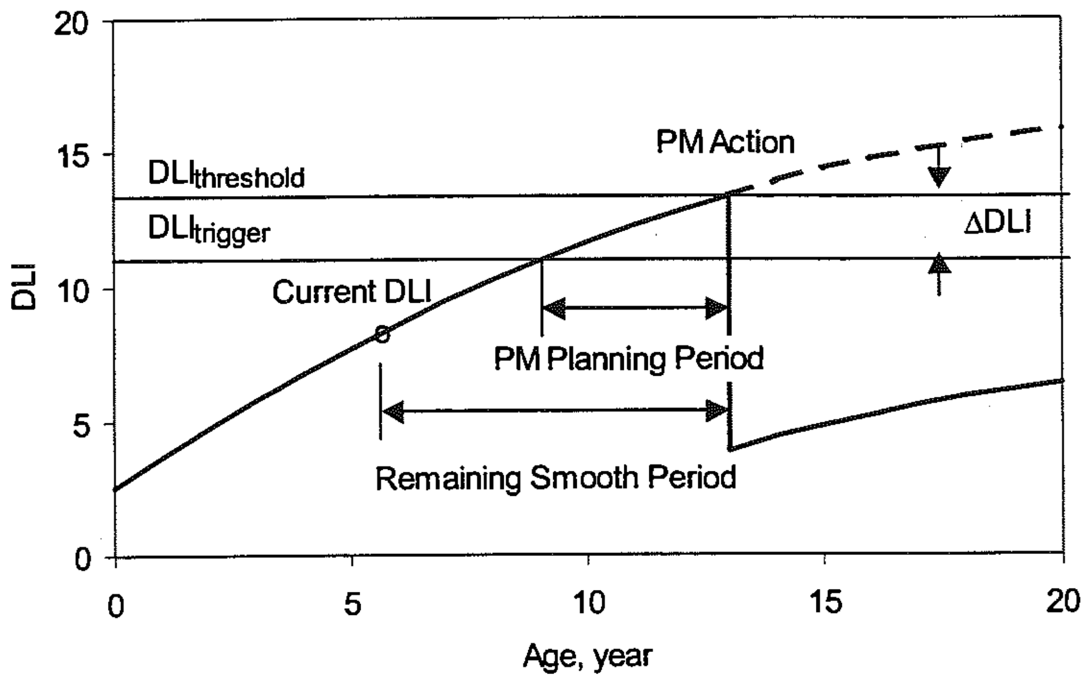


FIGURE 7.11 Schematic Figure of 'Remaining Smooth Period' and 'PM Planning Period'

CHAPTER 8
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter summarizes the main findings from this research, outlines the main conclusions from the study and their implications to pavement management and preventive maintenance application, and highlights areas in which further research is needed.

8.1 SUMMARY OF FINDINGS

The objective of this study was to investigate the interaction between surface roughness, dynamic truck loading and pavement damage for the purpose of determining roughness thresholds. These thresholds would be used in the pavement management system as an early warning for preventive maintenance action. This was done by testing the hypothesis that there is a certain level of roughness (roughness threshold-values) at which a sharp increase in dynamic load occurs, thus causing an acceleration in pavement damage accumulation.

- **Correlating Surface Roughness, Dynamic Loading and Pavement Distress**

  The analysis of roughness and distress profiles (at 0.1-mile sections) led to identifying zones of high distress and/or high roughness. Combining the above information with the trends of distress and roughness indices from year to year allowed for discerning dynamic load-related from non-load-related distress accumulation. Comparison of dynamic-load and distress-point profiles (at 10-foot intervals) along the length of a given pavement section showed that a reasonably good match between load and distress profiles is possible with relatively low ρ-values. A relatively high ρ-value indicates dynamic load-related distress accumulation, and a low ρ-value indicates that the distress accumulation is not primarily related to dynamic loading.

- **Development of Network-level RQI-DI Relationships**

  The MDOT PMS database was used to develop relationships between distress (Distress Index, DI) and roughness (Ride Quality Index, RQI) for all pavement types. Three independent data sets for a total of 97 projects, or 1,437 (0.5-mile) sections, that have different ages and levels of distress and roughness were used for this analysis.

  An attempt to isolate dynamic-load-related distresses from other distresses was made using the three independent data sets. The results from the first data set showed that for all three types of pavements, transverse crack with associated distress was dominant in relatively rough pavements; transverse joint deterioration, delamination and patch deterioration were also dominant in relatively rough rigid pavements. However, the results from the second and the third data sets did not agree with those from the first data set. Therefore dynamic load-related distress types could not be isolated. DI-RQI relationships for rigid pavements had the highest R^2-values (0.488, 0.699 and 0.731). Flexible pavements had the lowest R^2-values (0.311, 0.448 and 0.507), and composite pavements had in-between R^2-values (0.522, 0.511 and 0.0.603). Critical RQI-values corresponding to maximum distress acceleration were obtained from these relationships. These were 57, 54 and 57 for rigid pavements; and 44, 48 and 42 for composite pavements. For flexible pavements, critical RQI-values were found to be 45, 40 and 44; however, these values are not reliable because of the high scatter in the data. Probability analysis on DI-RQI curves showed a large variability in critical RQI-values. This variability is due to the fact that distress is caused not only by axle loads but also by many other factors. Finally, these critical values represent the overall behavior of pavements at the network level, and may not be applicable for a particular pavement project. Therefore, such thresholds can be used for network-level pavement management and not necessarily at the project level.

- **Development of Relationships between RQI and Dynamic Load**

For this analysis, actual surface profiles of 333 in-service pavement sections (0.1-mile long) from thirty-seven projects in Michigan were used to generate dynamic axle loads using the TruckSim™ truck simulation program. Good correlations were obtained between RQI and dynamic loading (Dynamic Load Coefficient, DLC, and 95th percentile dynamic load), and between RQI and pavement damage, with R^2 ranging from 0.85 to 0.95. Using the 4th power law, the relative damage from the 95th percentile dynamic load and the corresponding reduction in pavement life at different RQI levels were calculated. Based on these relationships, the critical RQI-values where the reduction in pavement life sharply increases were determined for rigid, flexible and composite pavements. The lower bound for the critical RQI-value was taken as that corresponding to the minimum slope of the curve, beyond which the rate of damage or reduction in pavement life starts increasing. These values were equal to 61, 50 and 47 for rigid, composite and flexible pavements, respectively. The upper bound for the critical RQI-value was taken as that corresponding to the maximum acceleration of the curve, where the rate of increase in the reduction of pavement life is highest. These values were equal to 77, 70 and 66 for rigid, composite and flexible pavements, respectively. The lower bound values agree better with the field-derived, DI-based values. This can be expected because distress accumulation should start some time after increased loading.

- **Development of a New Roughness Index for Predicting Dynamic Loads**

A new index, called Dynamic Load Index (DLI), was developed from the profile PSD curve. The new index is a better indicator of dynamic axle loading than the existing roughness indices including the RQI and the IRI (International Roughness Index). The DLI is calculated as a weighted index of variances of the profile elevation in the frequency ranges 1.5-4 Hz and 8-15 Hz. The first frequency range corresponds to truck body bounce, while the second frequency range corresponds to axle bounce. The analysis showed a very good correlation between DLI and dynamic load. The new index can differentiate between profiles that generate high dynamic loads and those having the same RQI but generating low dynamic loads. Most importantly, the use of the DLI negates the need for running a truck simulation program. This makes it possible to decide whether a particular pavement with a given surface profile needs smoothing based on the DLI-value. Thus the DLI can be used as a project-level roughness index for preventive maintenance aimed at extending pavement life by minimizing dynamic loads.

- **Development of Project-level Roughness Thresholds for Predicting Increased Dynamic Loads**

Relationships between DLI and theoretical pavement damage were developed using the mechanistic approach. Estimates of pavement life extension resulting from smoothing its surface were then generated for different Remaining Service Life (RSL) values. The results were presented in tables showing the expected life extension for a range of RSL- and DLI- values. These tables would enable a highway agency to determine when a particular pavement needs to be smoothed to obtain a given (desired) life extension. The analysis was done for the three pavement types (rigid, flexible and composite).

RSL-values were calculated for 0.5-mile sections from the first data set using actual distress growth over time. The results showed that for rigid pavements, 17% of sections with DLI between 7 and 11 and 51% of sections with DLI between 11 and 15 would have life extensions of more than 3 years. For composite pavements, none of the sections would have life extensions of 3 years or more. For flexible pavements, 9% of sections with DLI between 7 and 11 and 34% of sections with DLI between 11 and 15 would have life extensions of more than 3 years. These results indicate that preventive maintenance smoothing action is best suited for rigid pavements.

- **Determining Optimal Timing for Smoothing Preventive Maintenance Action**

A reliability-based model for predicting roughness growth with time was developed. The model uses DLI-growth rates that would be obtained from in-service pavements. Because there are no DLI data in the MDOT PMS database, and since MDOT has been collecting RQI data for many years, the analysis used RQI data in lieu of DLI data. Based on actual RQI-growth rates from 312 in-service pavement projects (112 rigid, 100 composite and 100 flexible pavements) totaling 4,422 (0.5-mile) sections, reliability tables were generated indicating the probabilities that the pavement will not reach the roughness threshold value before x years for different roughness trigger values, with x being the PM planning period. The model can be used to determine the optimal timing for smoothing PM action.

8.2 CONCLUSIONS

The research in this study was successful at validating the hypothesis that there is a certain level of roughness at which a sharp increase in dynamic load occurs, thus causing an acceleration in pavement damage accumulation. This was done by:

1. Identifying empirical relationships between roughness and distress using current indices (Ride Quality Index, RQI, for roughness and Distress Index, DI, for distress) from in-service pavements.
2. Developing similar relationships between surface roughness and theoretical pavement damage using the mechanistic approach.

The above relationships allowed for determining critical ranges of RQI, at which distress and theoretical pavement damage accelerate. Reasonable agreement was obtained between theoretically-derived and empirically-derived ranges. However, these RQI-ranges were too wide to be adopted at the project level. It was therefore concluded that the RQI was not suitable for predicting dynamic truck loads at the project level, i.e., for a specific pavement profile.

The new DLI roughness index that was developed to resolve the above-mentioned issue allows for identifying "unfriendly" pavement profiles from a dynamic truck loading aspect. The life extension tables developed using the DLI can be used to decide when smoothing action needs to be taken in order to get a desired life extension for a particular project. Comparison with RSL-values derived using actual distress growth over time from in-service pavements allowed for determining the optimal range of DLI-values that would lead to the desired life extension upon smoothing the pavement surface. The results showed that such preventive maintenance smoothing action is best suited for rigid pavements.

The model for predicting roughness growth with time that was developed can be used in conjunction with the roughness thresholds to determine the optimal timing for smoothing preventive maintenance action.

8.3 RECOMMENDATIONS

The results of this study yield the following recommendations.

- First, it is suggested that the new DLI roughness index be added to the PMS program. This would enable MDOT and the research team to monitor the DLI for the entire pavement network. Such action does not entail implementing the proposed preventive maintenance tables generated in Chapter 6; instead, this information would be used to verify/improve the life extension predictions generated in this study, and to support the development of future DLI growth models. The computer program for calculating the DLI was completed as part of this study; therefore its incorporation as an independent subroutine into the PMS program should be straightforward.

- Second, the development of the preventive maintenance strategy aimed at minimizing dynamic axle-loads needs to be verified in the field through the implementation of a prototype program for preventive maintenance. This could be achieved by:

  (1) Identifying pavement sections where preventive maintenance in the form of surface smoothing would be warranted. These sections would have a DLI-value at or above the threshold value. These sections should be recommended for distress evaluation (and FWD testing, if possible) to assess their structural integrity. Those sections with relatively good structural integrity would be smoothed. Within sections to be smoothed, it is recommended that a small portion of the pavement should be left (intentionally) without smoothing. These sections should be monitored in subsequent years to document the effects of preventive maintenance versus the do-nothing solution.

  (2) Identifying pavement sections where preventive maintenance in the form of surface smoothing was done. These sections would be analyzed to determine their DLI at the time of the PM action, and the DI growth after the PM action. This data would then be compared with the predictions made in this study (i.e., life extension tables)

  Either of the above undertakings would constitute the initiation of a prototype program, which could be part of a follow-up study.

- Third, a similar model to RQI growth model can be developed for the DLI. This can be done using the same approach described in Appendix C, except that DLI values would have to be calculated for all pavement sections used. Alternatively, it may be possible to develop a DLI growth model indirectly from the RQI growth model. A large number of projects will need to be selected such that they would represent a wide range of ages and distress conditions. This would need to be done for rigid, flexible and composite pavements separately. RQI- and DLI-values would be plotted against pavement age for all projects within a pavement type. The data analysis should take into account major rehabilitation and reconstruction activities, and – whenever possible – it should account for maintenance activities. Pavement age would be defined as the number of years from initial construction or after reconstruction, rehabilitation or smoothing maintenance action has taken place. The reliability tables used in the model can be developed under the assumption that the RQI/DLI growth-rate is reasonably uniform in different pavement conditions. In reality, it may be a function of age, traffic volume, distress level and so on. Therefore, these tables can potentially be refined such that they are divided by age, truck traffic volume or distress level. To investigate whether reliability is affected by these factors, the proportions by age, truck traffic volume or distress level can be plotted for 'success' and 'failure' cases. Definitions of 'success' and 'failure' are based on whether or not the critical roughness threshold is reached. A significant difference in the proportions among 'success' and 'failure' cases for a given factor would indicate that the particular factor (e.g., truck traffic volume) does affect the RQI/DLI growth-rate and therefore needs to be taken into account. If that were the case, separate reliability tables would need to be generated for different categories of the particular factor (e.g., low versus high truck traffic volume).

- Finally, relationships between DLI and DI could be sought in a similar approach to that described in Chapter 4. The advantage of such an endeavor would be to develop better relationships than RQI-DI. Ideally, such analysis would generate DLI thresholds based on PMS distress data. However, the high variability in distress data may lead to similar results to those obtained using the RQI, thus hindering the usefulness of such curves at the project level.

LIST OF REFERENCES

Abbo, E. " The Influence of Heavy Vehicle Dynamics on Rigid Pavements", Master's Thesis, Massachusetts Institute of Technology, 1987.

Ali, H.A. and Tayabji, S.D., "Evaluation of Mechanistic-Empirical Performance Prediction Models for Flexible Pavement", Transportation Research Record, 1629, Transportation Research Board, National Research Council, Washington D.C., 1998, pp. 169-180.

Bhattacharyya, G.K. and Johnson, R.A., "Statistical Concepts and Methods", John Wiley and Sons, New York, 1977.

Bendat, J.S. and Piersol, A.G., " Random Data : Analysis and Measurement Procedure" Second Edition, John Wiley and Sons, New York, 1986.

Cebon, D., "An Investigation of the Dynamic Interaction Between Wheeled Vehicles and Road Surfaces", Ph.D Dissertation, University of Cambridge, 1985.

Cebon, D., " Examination of the Road Damage caused by Three Articulated Vehicles", Proceedings 10^{th} IAVSD Symposium on the Dynamics of Vehicles on Roads and Trucks, Swets nad Zeitlinger, Prague, 1987.

Cebon, D., "Handbook of Vehicle-Road Interaction", Swets & Zeitlinger, Lisse, Netherlands, 1999.

Chatti, K., Mahoney, J.P., Monismith, C.L. and Moran, T., " Field Response and Dynamic Modeling of an Asphalt Concrete Pavement Section under Moving Heavy Trucks", Proceedings of the Fourth International Symposium on Heavy Vehicle Weights and Dimensions, Road Transport Technology-4, 1995, pp. 189-200.

Cole, D.J., " Measurement and Analysis of Dynamic Tyre Forces Generated by Lorries", Ph.D. Dissertation, University of Cambridge, UK, 1990.

Cole, D.J. and Cebon, D., " Spatial Repeatability of Dynamic Tyre Forces Generated by Heavy Vehicles", Proceedings of the Institution of Mechanical engineers, Journal of Automobile Engineering, Vol. 206, No D1, 1992, pp. 17-27.

Cole, D.J. and Cebon, D., "Modification of a Heavy Vehicle Suspension to Reduce Road Damage", Proceedings of the Institution of Mechanical engineers, Journal of Automobile Engineering, Volume 209, Part D, 1995, pp. 183-194.

Cole, D.J., Collop, A.C., Potter, T.E.C. and Cebon, D., "Spatial Repeatability of Measured Dynamic Tyre Forces", Proceedings of the Institution of Mechanical engineers, Journal of Automobile Engineering, Vol. 210, Part D, 1996, pp. 185-197.

Collop, A. and Cebon, D., "Modeling Whole-Life Pavement Performance", Proceedings of the Fourth International Symposium on Heavy Vehicle Weights and Dimensions, Road Transport Technology-4, 1995, pp. 201-212.

Collop, A.C., Potter, T.E.C., Cebon, D. and Cole, D.J., "Investigation of Spatial Repeatability Using a Tire Force Measuring Mat", Transportation Research Record, 1448, Transportation Research Board, National Research Council, Washington D.C., 1995, pp. 1-7.

Darlington, J., "The Michigan Ride Quality Index"; MDOT Document; December 1995.

de Pont, J. and Steven, B., "Suspension Dynamics and Pavement Wear', Presented at Accelerated Pavement Testing International Conference, Reno, Nevada, 1999.

Gillespie, T.D., Karamihas, S.M., Sayers, M.W., Nasim, M.A., Hansen, W, Ehsan, N. and Cebon, D., " Effects of Heavy-Vehicle Characteristics on Pavement Response and Performance", NCHRP Report 353, University of Michigan and Cambridge University, 1993.

Gillespie, T.D., "Fundamentals of Vehicle Dynamics", Society of Automotive Engineers, Warrendale, PA, 1992.

Gillespie, T.D., "Effect of heavy vehicle characteristics on pavement response and performance", The University of Michigan Transportation Research Institute, 1991.

Gillespie, T.D. and Sayers, M.W., "Role of Road Roughness in Vehicle Ride", Transportation Research Record, 836, Transportation Research Board, National Research Council, Washington D.C., 1981, pp. 15-20.

Gillespie, T.D., Sayers, M.W. and Segel, L., " Calibration of Response-Type Road Roughness Measuring System", NCHRP Report 228, University of Michigan, 1980.

Huhtala, M., "The Effect of Wheel Loads on Pavements", Proceedings of the Fourth International Symposium on Heavy Vehicle Weights and Dimensions, Road Transport Technology-4, 1995, pp. 235-241.

Hedrick, J.K., Markow, M.J. and Brademeyer, B., "The Simulation of Vehicle Dynamic Effects on Road Pavement", USDOT-Office of University Research Report, Massachusetts Institute of Technology, 1988.

Houbolt, J.C., "Runway Roughness Studies in the Aeronautical Field," Transactions of the American Society of Civil Engineering, Vol,127. Part 4, 1962, pp. 427-448.

Huang, Y.H., "Pavement Analysis and Design", Prentice Hall, New Jersey, 1993.

Hudson, W.R., " Road Roughness : Its Elements and measurement", Transportation Research Record, 836, Transportation Research Board, National Research Council, Washington D.C., 1981, pp. 1-7.

Jacob, B., " Spatial Repeatability of The Impact Forces on a Pavement and Multiple Sensor WIM-Research Element 5 of the OECD IR6 Divine Project", Proceedings of the Fourth International Symposium on Heavy Vehicle Weights and Dimensions, Road Transport Technology-4, 1995, pp. 273-279.

Johnson, K.D. and Cation, K.A., "Performance Prediction Development Using Three Indexes for North Dakota Pavement Management System", Transportation Research Record, 1344, Transportation Research Board, National Research Council, Washington D.C., 1992, pp. 22-30.

Jordal, P.R. and Rauhut, K.B., "Flexible Pavement Model VESYS IV-B", FHWA Report, Contract DTFH61-C-00175, 1983.

Kenis, W.J. and Jammouda, J., "Implementation of Road Profiles For Vehicle Dynamics Simulation", Proceedings of the Fourth International Symposium on Heavy Vehicle Weights and Dimensions, Road Transport Technology-4, 1995, pp. 333-340.

Kenis, W.J, Wang, W., "Analysis of Pavement Structural Variability", FHWA Report, No. FHWA-RD-97-072, 1997.

Kenis, W.J., Wang, W., "Pavement Variability and Reliability", Presented at Accelerated Pavement Testing International Conference, Reno, Nevada, 1999.

Kenis, W.J, Wang, W., " OECD DIVINE Element 1: Accelerated Dynamic Pavement Testing", FHWA Report, No. FHWA-RD-97-138, 1998.

Kenis, W.J., George, D. and Jammouda, J., " Pavement Primary Response to Dynamic Loading:, FHWA Report, No. FHWA-RD-97-073, 1997.

Kulakowski, B.T., "Vehicle-Road Interaction", ASTM, STP 1225, Philadelphia, PA, 1994.

LeBlanc, P.A. and Woodrooffe, J.H.F., "Spatial Correlation of Dynamic Wheel Loads", Proceedings of the Fourth International Symposium on Heavy Vehicle Weights and Dimensions, Road Transport Technology-4, 1995, pp. 281-290.

Lieh, J. and Qi, W., "Simulation of Dynamic Truck Loading on Pavements Using Measured Road Roughness", Transportation Research Record, 1501, Transportation Research Board, National Research Council, Washington D.C., 1995, pp. 13-21.

Liu, C., Herman, R. and McCullough, B.F., "Pavement Deterioration, Rate of Dynamic Force, and Ride Quality", Transportation Research Record, 1643, Transportation Research Board, National Research Council, Washington D.C., 1998, pp. 14-19.

Mamlouk, M.S. and Mikhail, M.Y., "Concept for Mechanistic-Based Performance Model for Flexible Pavements", Transportation Research Record, 1629, Transportation Research Board, National Research Council, Washington D.C., 1998, pp. 149-158.

Marcondes, J., Burgess, G.J., Harichandran, R. and Snyder, M.B., "Spectral Analysis of Highway Pavement Roughness", Journal of Transportation Engineering, Vol.117, No.5, 1991, pp. 540-549.

Marcondes, J.A., Synder, M.B. and Singh, S.P., "Predicting Vertical Acceleration in Vehicle Through Road Roughness", Journal of Transportation Engineering, Vol. 118, No.1, 1992, pp. 33-49.

Markow, M.J., Hedrick, J.K., Brademeyer, B.D. and Abbo, E., "Analyzing the Interactions Between Dynamic Vehicle Loads and Highway Pavements", TRB 1196, 1988, pp. 161-169.

Michigan DOT, "Evaluating Pavement Surface: LISA and RQI", *Materials & Technology Research Record*; Issue No. 79; June 1996.

Mikhail, M.Y. and Mamlouk, M.S., "Effect of Vehicle-Pavement Interaction on Pavement Response", Transportation Research Record, 1570, Transportation Research Board, National Research Council, Washington D.C., 1997, pp. 78-88.

Miner, M.A., "Cumulative Damage in Fatigue", Transportations of the ASME, Vol.67, 1945.

Moody, E.D., "Analysis of LTPP Profile Data for Jointed Concrete Pavement Sections", Transportation Research Record, 1570, Transportation Research Board, National Research Council, Washington D.C., 1997, pp 70-77.

Moran, T., Sullivan, M., Mahoney, J. and Chatti, K., "A Demonstration of The Theory of Spatial Repeatability", Proceedings of the Fourth International Symposium on Heavy Vehicle Weights and Dimensions, Road Transport Technology-4, 1995, pp. 291-300.

Mrad, N., El-Gindy, M. and Kenis, W., "Effects of Wheel-Load Spatial Repeatability on Road Damage: a Literature Review", FHWA Report, 1998.

Neter, J. and Wasserman, W., " Applied Linear Statistical Models : Regression, Analysis of Variance, and Experimental Designs", Richard D. Irwin, Inc, Homewood, IL, 1974.

Neter, J., Wasserman, W. and Whitmore, G.A., " Applied Statistics", Fourth Edition, Allyn and Bacon, 1993.

Newland, D.E., " An Introduction to Random Vibrations and Spectral Analysis", John Wiley and Sons, Inc., New York, 1984.

OECD, "Dynamic Loading of Pavements", OECD Road Transport Research, Paris, 1992.

Paterson, W.D.O. and Okine, B.A., "Summary Models of Paved Road Deterioration Based on HDM-III", Transportation Research Record, 1344, Transportation Research Board, National Research Council, Washington D.C., 1992, pp. 99-105.

Perera, R.W., Byrum, C. and Kohn, S.D., " Investigation of Development of Pavement Roughness", FHWA Report, No.FHWA-RD-97-147, 1998.

Rowshan, S., " Performance Prediction Model Based on Roughness in Asphalt Concrete Pavements", Ph.D. Dissertation, University of Maryland , Colleage Park, MD, 1998.

Saraf, C.L. and Majidzadeh, K., " Distress Predictin Models for a Network-Level Pavement Management system", Transportation Research Record, 1344, Transportation Research Board, National Research Council, Washington D.C., 1992, pp. 38-48.

Sayers, M.W., "Profiles of Roughness", Transportation Research Record, 1260, Transportation Research Board, National Research Council, Washington D.C., 1990, pp. 106-111.

Sayers, M.W., "On the Calculation of International Roughness Index from Longitudinal Road Profile", Transportation Research Record, 1501, Transportation Research Board, National Research Council, Washington D.C., 1995, pp. 1-12.

Sayers, M.W., Gillespie, T.D. and Queivoz, C.A.V., "The International Road Roughness Experiment : A Basis for Estabiliching a Standard Scale for Road Roughness Measurements", Transportation Research Record, 1084, Transportation Research Board, National Research Council, Washington D.C., 1986, pp. 76-85.

Singh, S.P., " Predicting Vertical Acceleration in Vehicles through Road Roughness", Journal of Transportation Engineering, Vol.117, No.5, 1991.

Smith, K.D., Hoerner, T.E. and Darter, M.I., " Effect of Initial Pavement Smoothness on Future Smoothness and Pavement Life", Transportation Research Record, 1570, Transportation Research Board, National Research Council, Washington D.C., 1997, pp. 60-69.

Smith, K.L., Smith, K.D., Evans, L.D., Hoerner, T.E., Darter, M.I. and Woodstrom, J.H., " Smoothness Specifications for Pavements", NCHRP Report, 1997.

Streit, D.A., Kulakowski, B.T., Sebaaly, P.E., and Wollyung, R.K., " Road Simulator Study of Heavy-Vehicle Wheel Forces", FHWA Report, No. FHWA-RD-98-019, 1998.

Ullidtz, P and Forlag, P., "Modeling Flexible pavement Response and Performance", Narayana Press, Gylling, 1998.

Ullidtz, P, "Pavement Analysis", Elsevier, New York, 1987.

Van Deusen, B.D. and McCarron, G.E., "A New Technique for Classifying Random Surface Roughness", SAE Transaction 670032, pp. 194-203.

Wambold, J.C., Defrain, L.E., Hegmon, R.R., McGhee, K., Reichert J. and Spangler, E.B., "State of the Art of Measurement and Analysis of Road Roughness", Transportation Research Record, 836, Transportation Research Board, National Research Council, Washington D.C., 1981, pp. 21-29.

Wambold, J.C., Defrain, L.E., Hegmon, R.R., McGhee, K., Reichert, J. and Spangler, E.B., "State of the Art of Measurement and Analysis of Road Roughness", Transportation Research Record, 836, Transportation Research Board, National Research Council, Washington D.C., 1981, pp. 21-29.

Wenzel, T.H., Abadi, F.V., Shober, S.F. and Schmiedlin, R., "Effects of Spot Diamond Crinding on Performamce of Portland Cement Concrete Pavements", Transportation Research Record, 1629, Transportation Research Board, National Research Council, Washington D.C., 1998, pp. 197-207.

Woodrooffe, J.H.F. and LeBlanc, P.A., " Spatial Correlation of Dynamic Wheel Loads", Proceedings of the Fourth International Symposium on Heavy Vehicle Weights and Dimensions, Road Transport Technology-4, 1995.

Yoder, E.J.," Principles of Pavement Design", Wiley, New York, 1959.

GLOSSARY OF KEY TERMS

Capital Preventive Maintenance* - "Preventive maintenance is a planned strategy of cost-effective treatments to an existing roadway system and its appurtenances that preserves, retards future deterioration and maintains or improves the functional condition of the system without (significantly) increasing structural capacity." Preventive maintenance is applied to pavements having a remaining service life of three years or greater. Examples of capital preventive maintenance include bituminous crack sealing, chip sealing, micro-surfacing, concrete joint resealing, concrete crack sealing, thin bituminous overlays, diamond grinding, full depth concrete repairs, and dowel bar retrofit.

Design Life* - The anticipated life of the pavement section at the time of initial construction. Design life, as fix life, does not include any additional life estimates provided by anticipated future preventive maintenance. This term is also used to define the number of years for which design Equivalent Single Axle Loads are calculated as an input parameter for formal pavement design calculations.

Distress Index, DI* - An index that quantifies the level of distress that exists on a pavement section based on 1/10th mile increments. The scale starts at zero and increases numerically as distress level increases (pavement condition worsens).

Dynamic Load - Load that varies in magnitude with time as it moves along the surface. The variation depends on the speed of the vehicle, unevenness of the road, and the make up of the vehicle's suspension and tire characteristics.

Dynamic Load Coefficient, DLC - A parameter used to characterize the magnitude of dynamic wheel load. It is defined as the standard deviation of the dynamic load profile normalized by the mean load.

Dynamic Load Index, DLI – A roughness index representing truck dynamic axle loading. It is calculated as the square root of the weighted sum of variances of the profile elevation in the wavelength ranges of 6-11 ft and 22-59 ft, corresponding to frequency ranges of 1.5-4 Hz and 8-15 Hz at 60 mph. The first frequency range corresponds to truck body bounce, while the second frequency range corresponds to axle bounce.

Equivalent Axle Load Factor, EALF - The damage per pass to a pavement by the axle in question relative to the damage per pass of a standard axle load (18-kip single axle).

Fast Fourier Transform, FFT - A mathematical set of functions that transforms any random variable from space or time domain into wave number or frequency domain, respectively.

---

* MDOT Pavement Management Definition.

Fix Life* - The anticipated pavement life provided by the fix, excluding any future preventive maintenance treatments.

International Roughness Index, IRI – An index that summarizes the longitudinal surface profile in the wheel path, and is computed as the average ratio of the accumulated suspension motion to the distance traveled. It is obtained from a mathematical model of a standard quarter car traversing a measured profile at a speed of 50 mph (80 km/h), and is expressed in units of inches per mile (m/km).

Life Extension - The anticipated pavement life provided by the preventive maintenance treatment.

Pavement Damage - The deterioration of a pavement due to stresses caused by repeated load applications and environmental factors.

Pavement Management System, PMS - An established, documented procedure treating many or all of the pavement management activities including planning, budgeting, design, construction, monitoring, research, etc.

Preventive Maintenance – See Capital Preventive Maintenance.

Preventive Maintenance Planning Period, PMP - The number of years needed for planning preventive maintenance action.

Power Spectral Density, PSD - The distribution of the variance of a variable such as elevation over frequency.

Present Serviceability Index, PSI - Index of the ability of a pavement section to serve traffic in its existing condition. It ranges from 0 (very poor) to 5 (very good). The PSI is a function of road surface roughness and distresses.

Reactive Maintenance* - Reactive maintenance is an activity that must be done in response to events beyond the control of the Department. Reactive maintenance cannot be scheduled because events occur without warning and often must be immediately addressed. Examples of reactive maintenance activities include snow plowing, pothole patching, removing and patching pavement blowups, unplugging drainage facilities, replacing a regulatory sign knocked down by traffic, removing tree limbs and branches fallen on the pavement, cleaning and inspecting underdrains, and responding to a road closing because of flooding.

Rehabilitation* - A fix that has an estimated design or fix life of ten to twenty years. Rehabilitation fixes are typically applied to pavements with a remaining service life of two years or less. These fixes include: two or three course bituminous overlays, concrete patching & diamond grinding, crush & shape with bituminous overlay, rubblize & multiple course bituminous overlay, and unbonded concrete overlays.

---

* MDOT Pavement Management Definition.

Remaining Service Life, RSL* - The estimated number of years, from a specified date in time, until a pavement section reaches the threshold distress index. RSL is a function of the distress level and rate of deterioration.

Remaining Smoothing Period, RSP - The estimated number of years, from a specified date in time, until a pavement section reaches the threshold roughness level. RSP is a function of the roughness level and rate of roughness of growth.

Ride Quality Index, RQI* - An index developed by Michigan that quantifies the user's perception of pavement ride quality. It is reported in tenth mile increments. The scale starts at zero and increases numerically as ride quality decreases.

Routine Maintenance* - Routine maintenance is the day-to-day maintenance activities that are scheduled or whose timing is within the control of maintenance personnel. Examples of routine maintenance activities include mowing and cleaning roadsides, cleaning ditches, sealing cracks in the pavement, painting pavement markings and pruning trees.

Service Life (Analysis Period)* - The anticipated life of a rehabilitation or new/reconstruction, including additional pavement life provided by anticipated future preventive maintenance. This term is used to describe the number of years from the initial new construction, reconstruction or rehabilitation of a pavement to a subsequent rehabilitation or reconstruction. A service life or analysis period equals the sum of the original design/fix life plus any additional pavement life provided by future anticipated preventive maintenance. Analysis period is the term typically used to describe the time used in a life cycle cost analysis.

Static Load - Load that is constant with time.

Threshold Distress Index* - A pavement condition level where a rehabilitation or reconstruction should be considered. The threshold distress index is equal to fifty.

Threshold Ride Quality Index* - The threshold index for poor pavement ride quality is equal to seventy.

Wavelength - Length of the cycle of a periodic function in space domain.

---

* MDOT Pavement Management Definition.

APPENDICES

APPENDICES

APPENDIX A
ANALYSIS ON LOAD-RELATED DISTRESS TYPES

Distress in pavements is caused not only by truck loads but also by many other factors such as material and environmental factors. For this reason, the relationship between distress and roughness is complex. If dynamic load-related distress types can be isolated from the other distress types, a better relationship between distress and roughness could be obtained.

An attempt to isolate dynamic load-related distress types was made using the first data set. For this analysis, several subsections having the same range in DI level but different RQI levels were selected. Table A.1 shows the criteria for selection and the number of sections selected for each DI range from the first data set. In this analysis, 0.5-mile sections were used instead of 0.1-mile sections to minimize any shifts between roughness and distress data. For each selected subsection, distress points of each distress type were calculated. In this calculation, transverse and longitudinal cracks were divided into two types: i) cracks having no associated distress; and ii) cracks with associated distress such as spalling. Associated distress is a distress occurring around a main distress, and is used to define subsequent deterioration of the main distress in MDOT PMS. In Figures A.1, A.2 and A.3, proportions of distress points of each distress type are plotted for relatively rough and relatively smooth subsections at each DI level (see Table A.1 for criteria used). These figures show that for rigid pavements, transverse cracks with associated distress, transverse joint deterioration, delamination and patch deterioration appear to be dominant in relatively rough sections at most DI levels while transverse cracks without associated distress are dominant in relatively smooth sections at most DI levels. For flexible and composite pavements, transverse cracks with associated distress appear to be dominant in relatively rough sections. For the first data set, it was possible to differentiate dynamic-load-related distress types from other distresses. However, further analysis conducted using the second and third independent data sets did not support this conclusion.

For the second and third data sets, the same analysis was done to isolate dynamic-load-related distress types. The criteria of section selection and the number of subsections selected from the second and third data sets together are shown in Table A.2. In Figures A.4, A.5 and A.6, proportions of distress points of each distress type are plotted for relatively rough and relatively smooth subsections at each DI level. These figures show that for rigid pavements, unlike the results from original data set, transverse cracks with associated distress are dominant in relatively smooth sections at high DI levels, while transverse joint deterioration is dominant in relatively smooth sections at low DI levels. For composite pavements, there is no major difference in proportions of transverse cracks with associated distress between rough and smooth sections at high DI levels. For flexible pavements, transverse cracks with associated distress are dominant in smooth sections and longitudinal cracks are dominant in rough sections at high DI levels. These results do not agree with those from the original data set. Therefore, it was concluded that dynamic load-related distress types could not be isolated.

TABLE A.1 Criteria of Section Selection and Number of Samples used for Dynamic Load-Related Distress Analysis using the First Data Set

a) Rigid Pavements

* Number of samples are in parenthesis

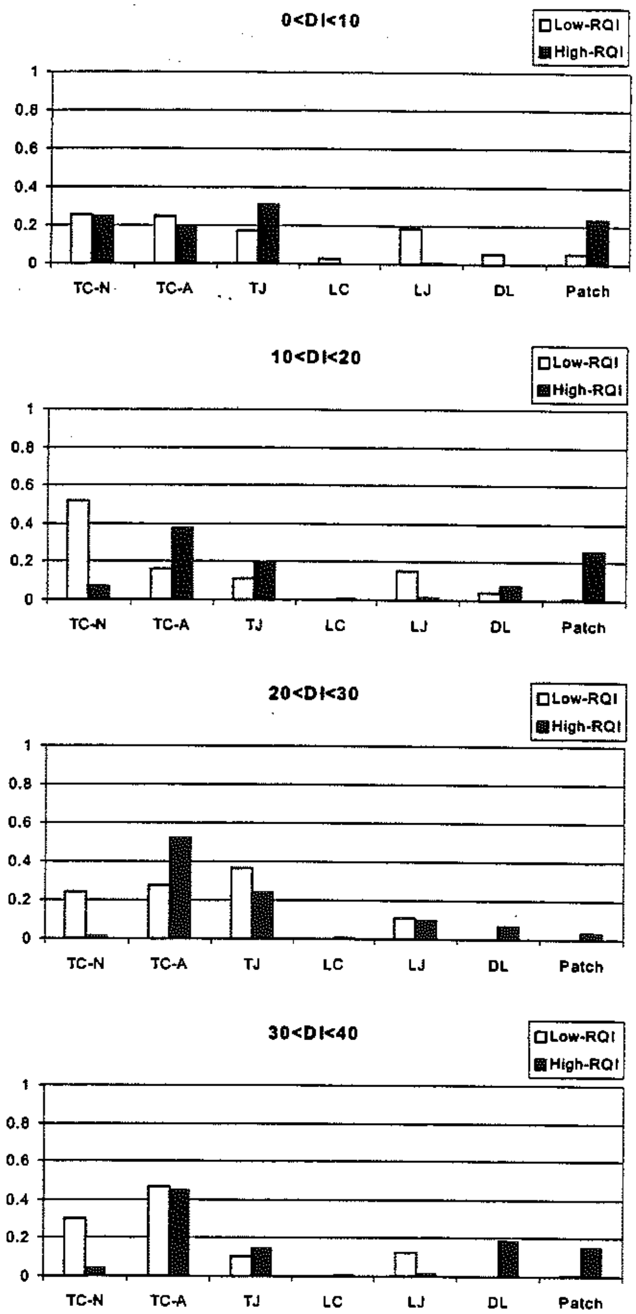
Relative Roughness	DI Level			
	0-10	10-20	20-30	30-40
Smooth	RQI<50 (11)	RQI<55 (17)	RQI<65 (4)	RQI<60 (4)
Rough	RQI>65 (10)	RQI>70 (17)	RQI>80 (4)	RQI>75 (4)

b) Flexible Pavements

Relative Roughness	DI Level				
	10-20	20-30	30-40	40-50	50-60
Smooth	RQI<35 (12)	RQI<40 (5)	RQI<40 (9)	RQI<40 (6)	RQI<40 (2)
Rough	RQI>55 (8)	RQI>60 (4)	RQI>60 (4)	RQI>60 (2)	RQI>60 (6)

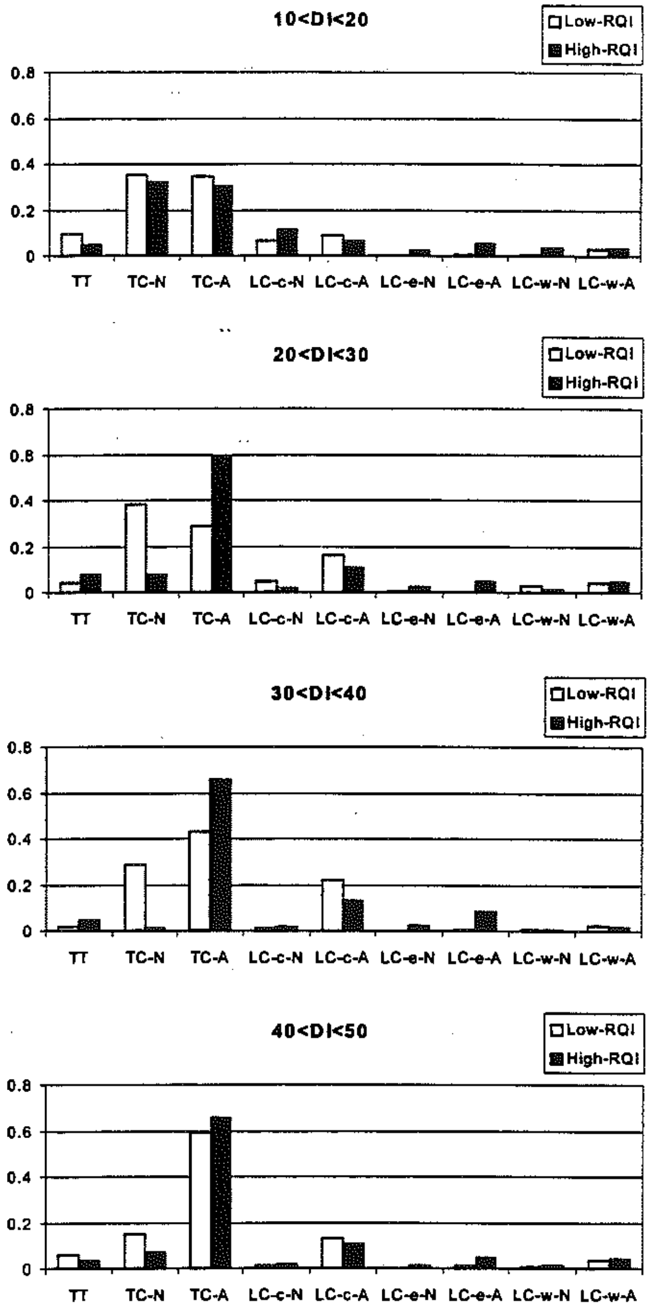
c) Composite Pavements

Relative Roughness	DI Level			
	10-20	20-30	30-40	40-50
Smooth	RQI<40 (9)	RQI<40 (5)	RQI<45 (5)	RQI<55 (4)
Rough	RQI>55 (8)	RQI>60 (4)	RQI>60 (7)	RQI>62(4)



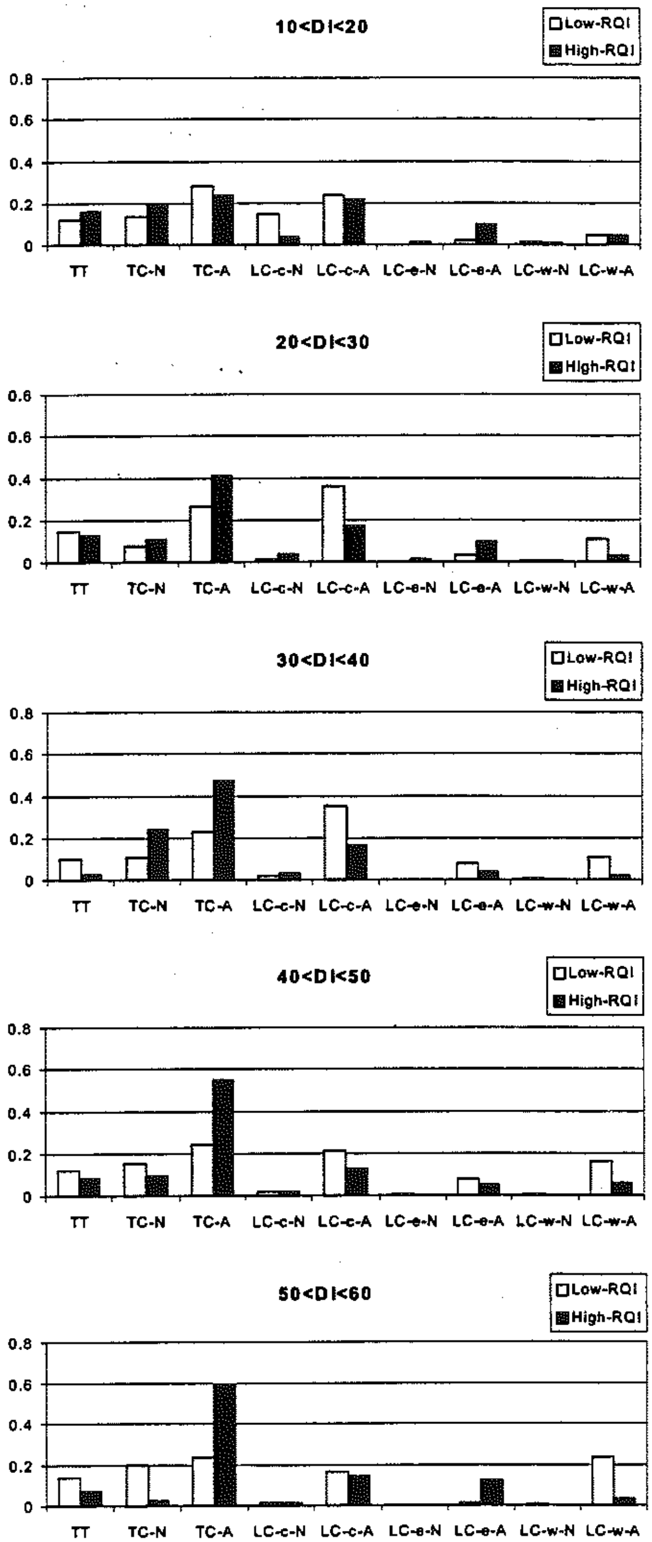
TC : Transverse Crack
TJ : Transverse Joint Deterioration
DL : Delamination
-N : with No Associated Distress
-A : with Associated Distress

FIGURE A.1 Proportions of Distress Types in the Distress Index for Rigid Pavements from Data Set #1



LC : Longitudinal Crack
LJ : Longitudinal Joint
TT : Transverse Tear
-c : at center line
-e : at edge
-w : at wheel path

FIGURE A.2 Proportions of Distress Types in the Distress Index for Composite Pavements from the Data Set #1



Abbreviations in this figure are the same as in Figure A.2.

FIGURE A.3 Proportions of Distress Types in the Distress Index for Flexible Pavements from the Data Set #1

TABLE A.2 Selection Criteria and Number of Samples for Dynamic Load-Related Distress Analysis using the Second and the Third Data Sets

a) Rigid Pavements   * Number of samples are in Parenthesis

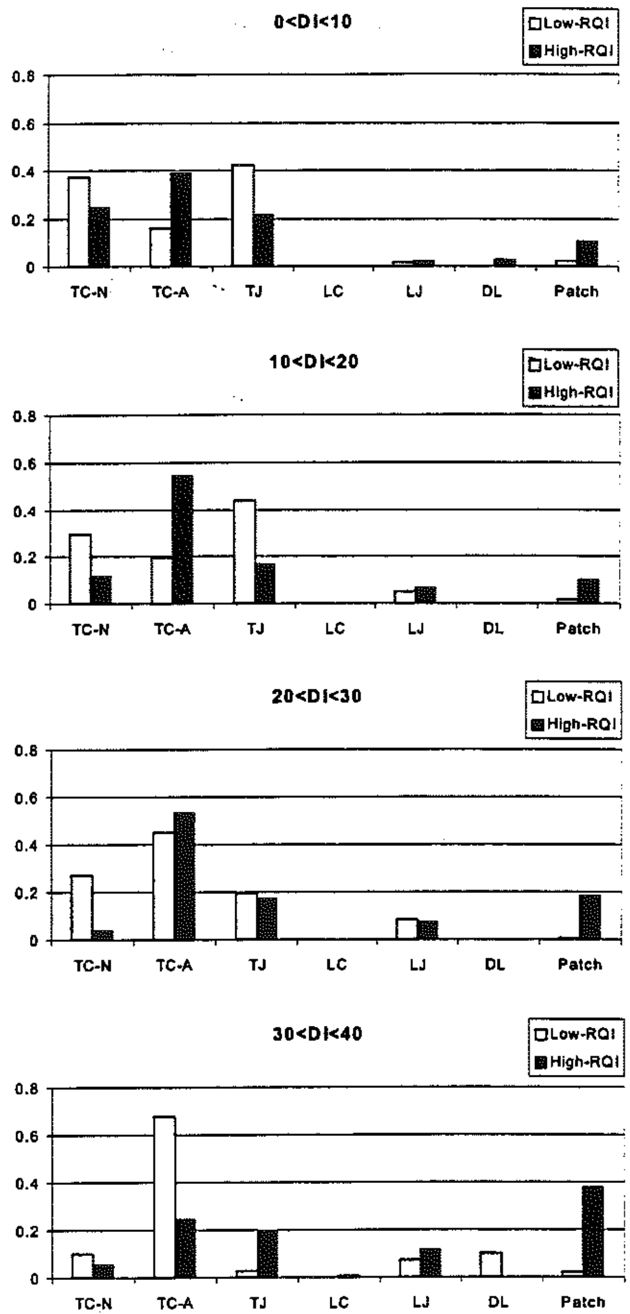
Relative Roughness	DI Level			
	0-10	10-20	20-30	30-40
Smooth	RQI<50 (10)	RQI<55 (14)	RQI<63 (8)	RQI<70 (5)
Rough	RQI>66 (12)	RQI>77 (12)	RQI>80 (6)	RQI>80 (5)

b) Flexible Pavements

Relative Roughness	DI Level			
	10-20	20-30	30-40	40-50
Smooth	RQI<25 (12)	RQI<40 (10)	RQI<40 (12)	RQI<55 (10)
Rough	RQI>45 (13)	RQI>55 (11)	RQI>62 (12)	RQI>66 (9)

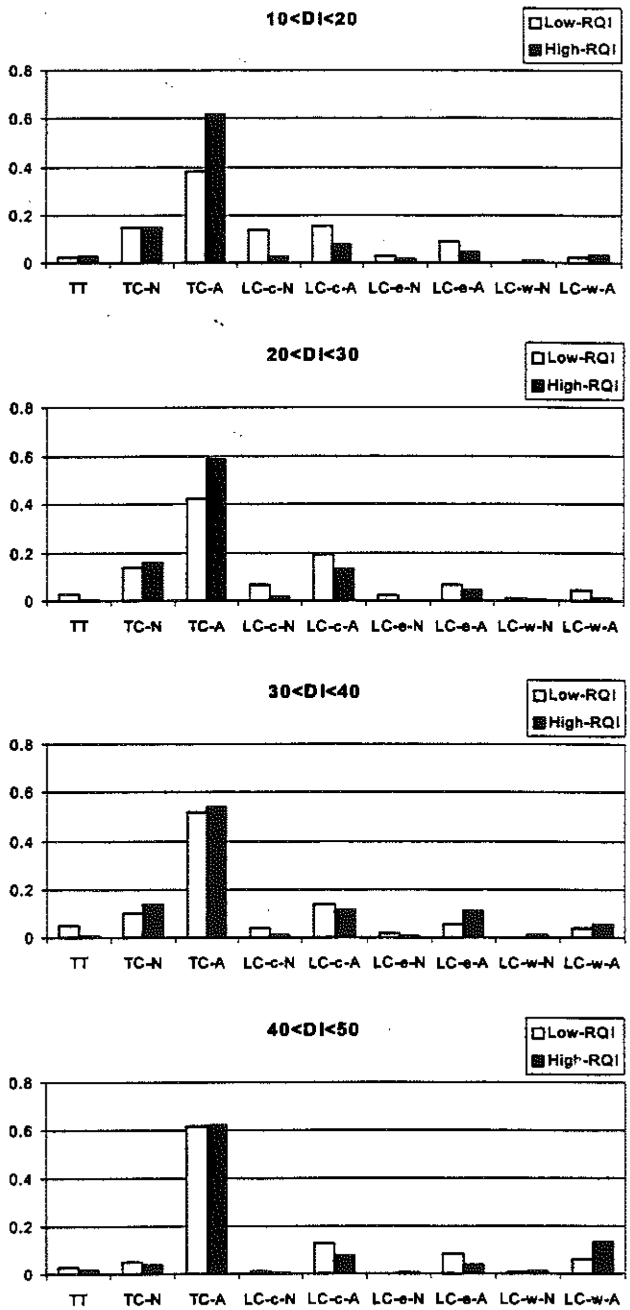
c) Composite Pavements

Relative Roughness	DI Level			
	10-20	20-30	30-40	40-50
Smooth	RQI<40 (10)	RQI<45 (5)	RQI<50 (6)	RQI<60 (9)
Rough	RQI>55 (15)	RQI>60 (9)	RQI>65 (5)	RQI>68(4)



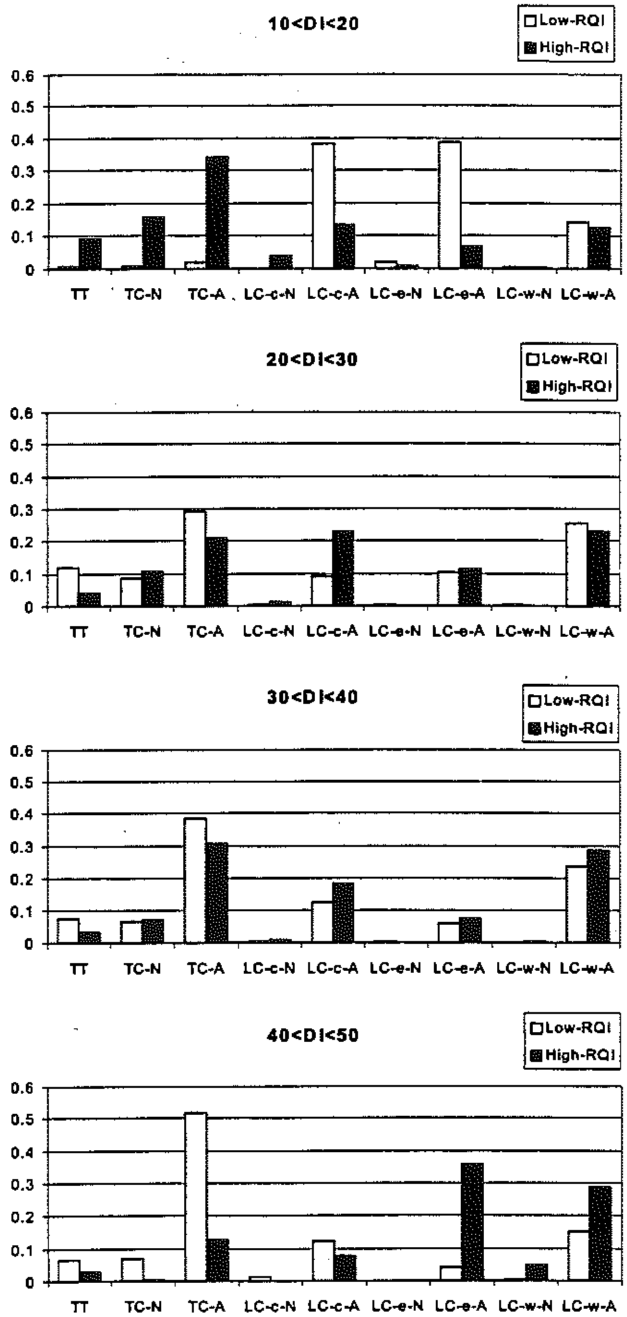
TC : Transverse Crack
TJ : Transverse Joint Deterioration
DL : Delamination
-N : with No Associated Distress
-A : with Associated Distress

FIGURE A.4 Proportions of Distress Types in the Distress Index for Rigid Pavements from Data Sets #2 and #3



LC : Longitudinal Crack
LJ : Longitudinal Joint
TT : Transverse Tear
-c : at center line
-e : at edge
-w : at wheel path

FIGURE A.5 Proportions of Distress Types in the Distress Index for Composite Pavements from Data Sets #2 and #3



Abbreviations in this figure are the same as in Figure A.5

FIGURE A.6 Proportions of Distress Types in the Distress Index for Flexible Pavements from Data Sets #2 and #3

APPENDIX B
PROBABILITY ANALYSIS ON THE RQI-DI RELATIONSHIPS

The critical RQI-values obtained from the DI-RQI curves are average values because they were determined based on the collective data obtained from many projects having different ages (i.e. different distress and roughness levels). Ideally, such values should be determined by statistical analysis of critical values determined from a large number of individual projects. Unfortunately, with the limited data (from 1992 to 1997), it is not possible at this time to determine a critical value from individual projects. So, alternatively, distress and roughness data from several projects were lumped together and critical values were determined from the best fitting curve. The scatter of data points around the best-fit curve implies that critical values from individual projects are different, and that they scatter around the mean values determined from best-fit curves. Given that there is insufficient data from individual projects to determine project values, it would be useful to know how critical values of individual projects are distributed around the mean value. Assuming that distress data points have a normal distribution at each RQI, 50% of DI data points lie between two values that are equal to the mean $\pm$ 0.675 σ at a given RQI-value, where σ = standard deviation of the DI. So, the upper and lower bands of data with a probability of 50% lie between curves with DI $\equiv$ mean $\pm$ 0.675σ. These upper and lower bands give critical values for the corresponding probability. The statistical analysis was done according to the following steps:

1. Calculate the standard deviation (σ) of DI at each RQI-value using all data sets (original set and independent sets).
2. Find best-fit curves using the logistic model.
3. Add and subtract 0.675σ to and from best-fit curves to get upper and lower limit points.
4. Fit upper and lower limit points using the logistic model.
5. Calculate critical values for the upper and lower band curves.

For rigid pavements, these two curves have critical values of 52 (upper curve) and 60 (lower curve). These results indicate that 50% of rigid pavement sections analyzed have critical RQI-values between 52 and 60. In other words, the 50% confidence interval for the critical value is 52 and 60. This analysis was done for rigid, composite and flexible pavements at probability values of 60% (corresponding to $\pm$ 0.842 σ), 70% ($\pm$ 1.034 σ), 80% ($\pm$ 1.282 σ) and 90% ($\pm$1.645 σ), where m $\equiv$ mean of the DI. Upper and lower band curves for each probability is shown in Figures B.1, B.2 and B.3 for rigid, composite and flexible pavements, respectively. The corresponding range in critical RQI values is shown in Table B.1.

The results show a wide range of critical values. With a probability of 70%, critical RQI-values range from 51 to 65 for rigid pavements, 40 to 57 for composite pavements, and 35 to 54 for flexible pavements. This indicates that critical values determined from lumping different projects could be used at the network level; however they are not accurate enough to be applied at the project level. This large variability in critical values comes from the fact that distress is caused not only by truck loads but also by many other factors. For example, some pavements could have a very low critical RQI-value if it has material problems. In this case, even if the pavement surface is smoothed at the time the critical RQI-value is reached, an increase in the rate of pavement damage cannot be reduced because the main cause of damage is not related to dynamic loads; rather it stems from other material-related factors. Such a pavement should therefore be subjected to a different maintenance action.

TABLE B.1 Critical RQI Values at Different Probabilities

Probability (%)	Rigid Pavements	Composite Pavements	Flexible Pavements
50	52-60	41-52	37-49
60	51-62	41-54	36-52
70	51-65	40-57	35-54
80	50-70	39-59	35-59
90	49-80	39-62	34-63

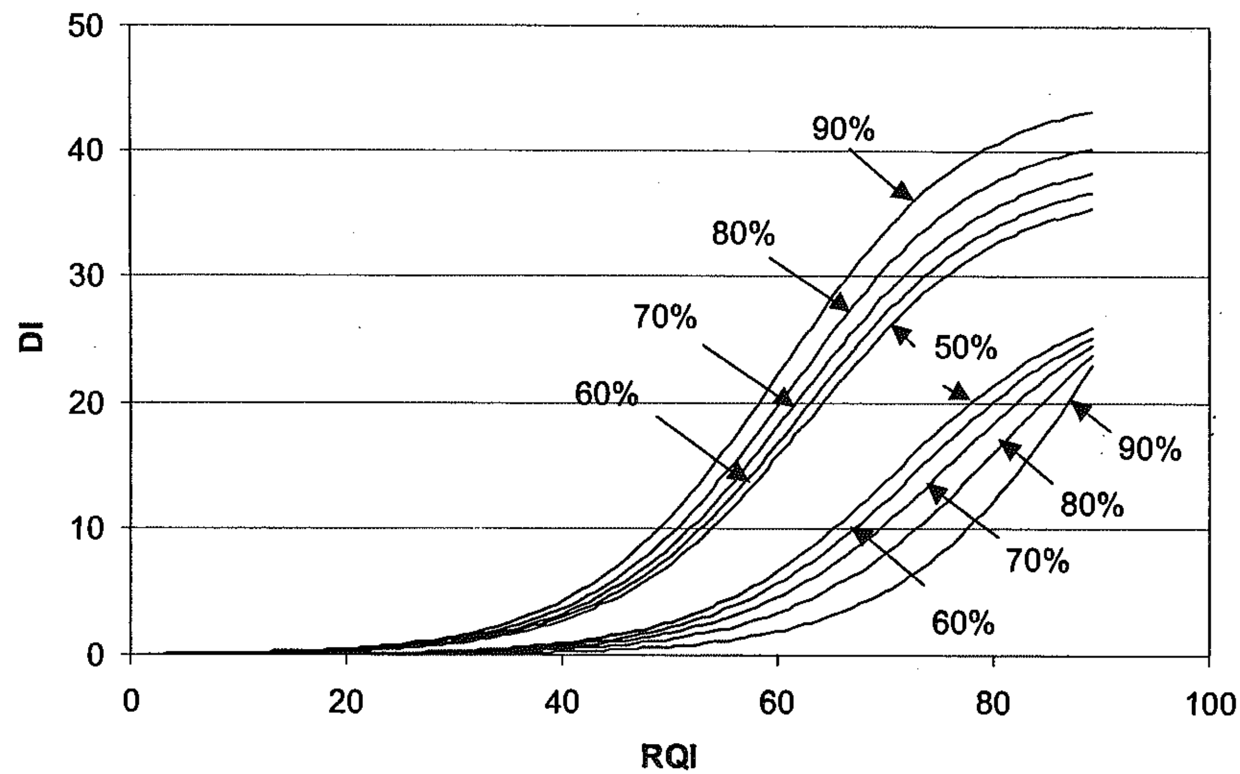


FIGURE B.1 Confidence Intervals for DI-RQI Relationship for Rigid Pavements

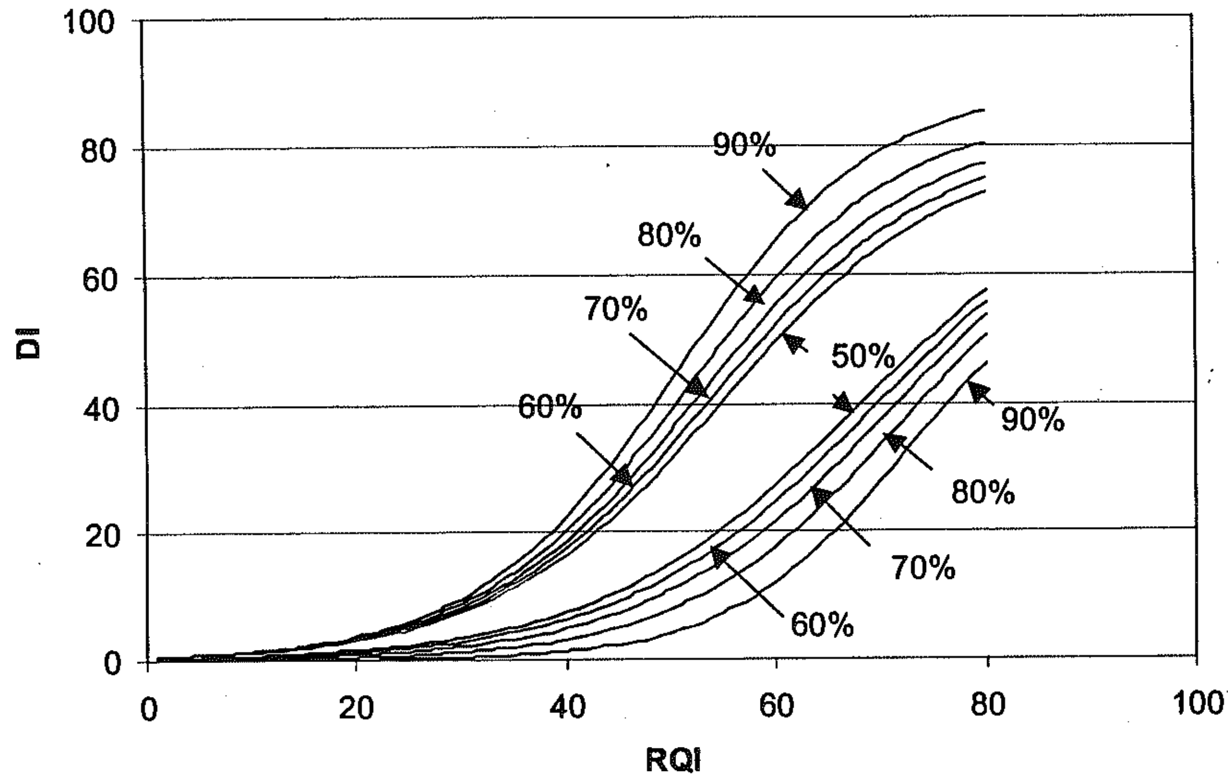


FIGURE B.2 Confidence Intervals for DI-RQI Relationship for Composite Pavements

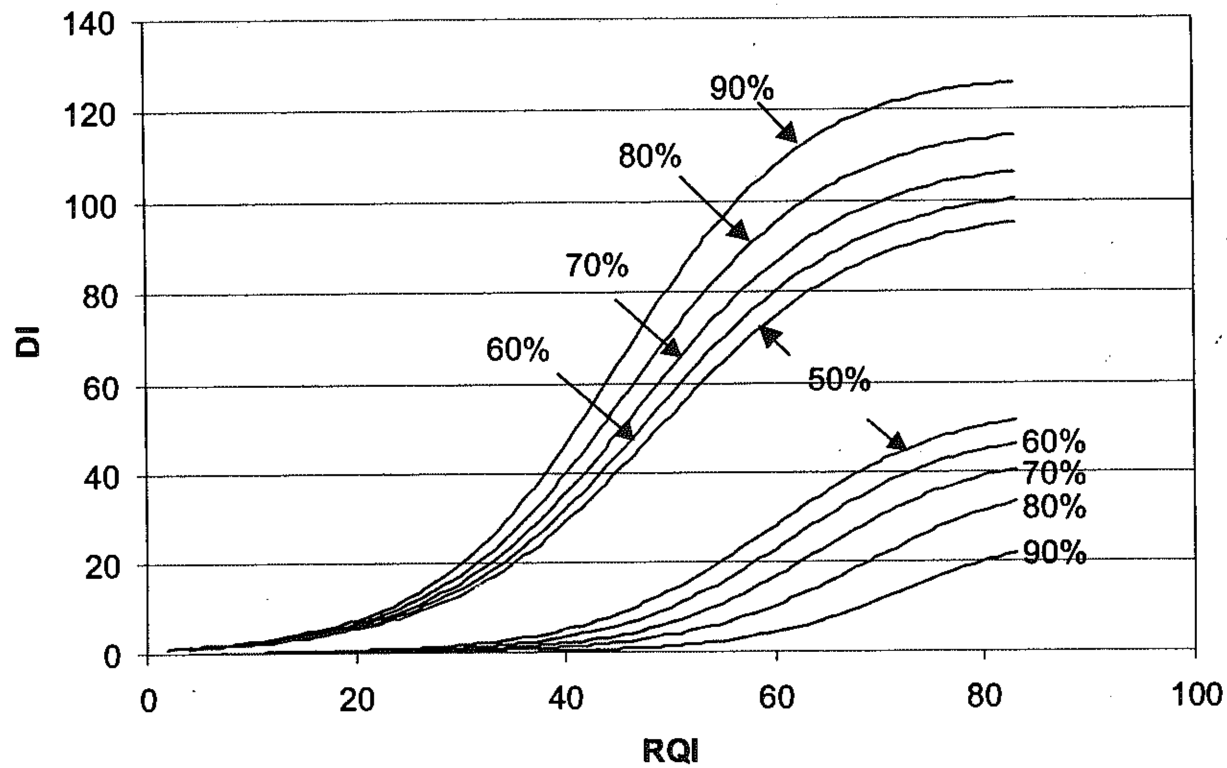


FIGURE B.3 Confidence Intervals for DI-RQI Relationship for Flexible Pavements

APPENDIX C
DEVELOPMENT OF A PREVENTIVE MAINTENANCE STRATEGY FOR MINIMIZING ROUGHNESS-RELATED PAVEMENT DAMAGE

1.0 INTRODUCTION

Roughness criticals aimed at minimizing dynamic loads can play an important role in pavement management and preventive maintenance (PM) program. If a PM action, in the form of smoothing the pavement surface, is taken when the critical RQI-value is reached it could extend the service life of the pavement by several years, since it will reduce roughness-generated dynamic loads. The ability to predict RQI growth with time would then be necessary in order to accurately predict the optimum timing for the preventive maintenance action. Ideally, it would be desired to have the ability to predict future RQI-values given a current RQI. This would enable the PM division within MDOT to plan roughness-related PM actions a few years prior to the pavement reaching the RQI critical-value. In this chapter, several approaches were used to predict future RQI-values, with the most promising one being a reliability-based model. The model allows for selecting the optimal timing (or planning period) of such preventive maintenance action (assuming one knows the critical RQI-value at which smoothing is warranted) using actual RQI-growth rates from in-service pavements.

2.0 RQI GROWTH WITH TIME

2.1 RQI Growth Model Using Existing Pool of Projects

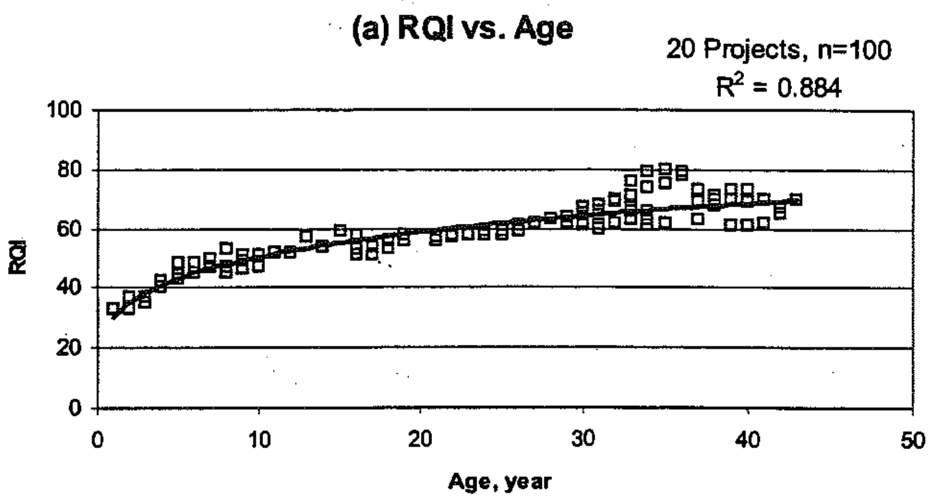
RQI-values for all rigid pavements in the existing pool of projects that were used to determine the RQI critical were plotted against pavement age. The data set consists of 20 projects for a total of 100 data points. The resulting curve for RQI growth with age is shown in Figure C.1. While the data shows a very good fit with R^2=0.88, there are only one to three projects per given age. Because this number is very low, it was decided to expand the pool of projects used to develop the RQI growth model, as described in the next section.

2.2 RQI Growth Model Using Expanded Pool of Projects

To develop the new RQI growth model for rigid pavements, 112 projects including the above projects were selected. The criteria of project selection are:

- Minimum project length of 1.0 mile;
- Interstate or US Highway;
- Age less than 35 years.

RQl vs. Age for all projects were plotted as shown in Figure C.2. The data show more scatter than that of Figure C.1, with an R^2 value of 0.59 as compared to 0.88 using 20 projects. Note that the data show a peak in the RQl at about 17 years followed by a temporary decrease in RQI. This could be due to maintenance activities that were



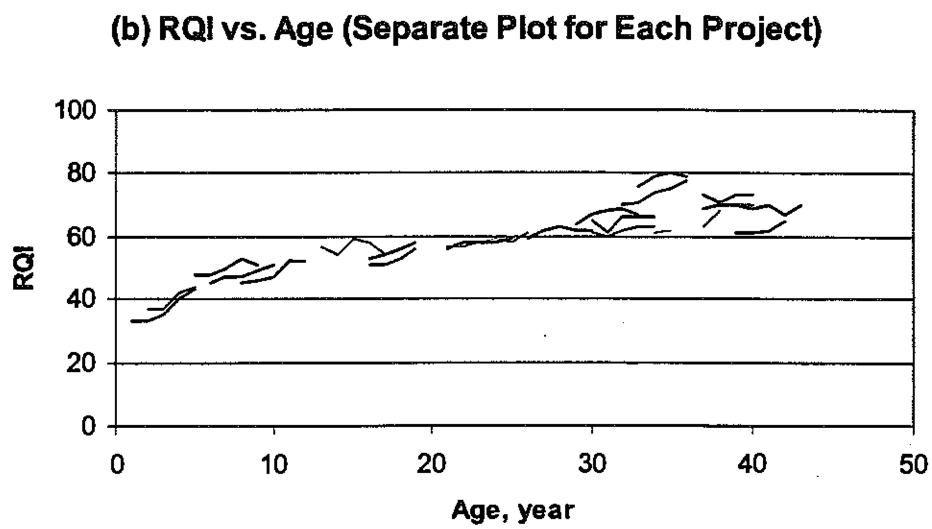


FIGURE C.1 RQI vs. Age using 20 Projects - Rigid Pavements

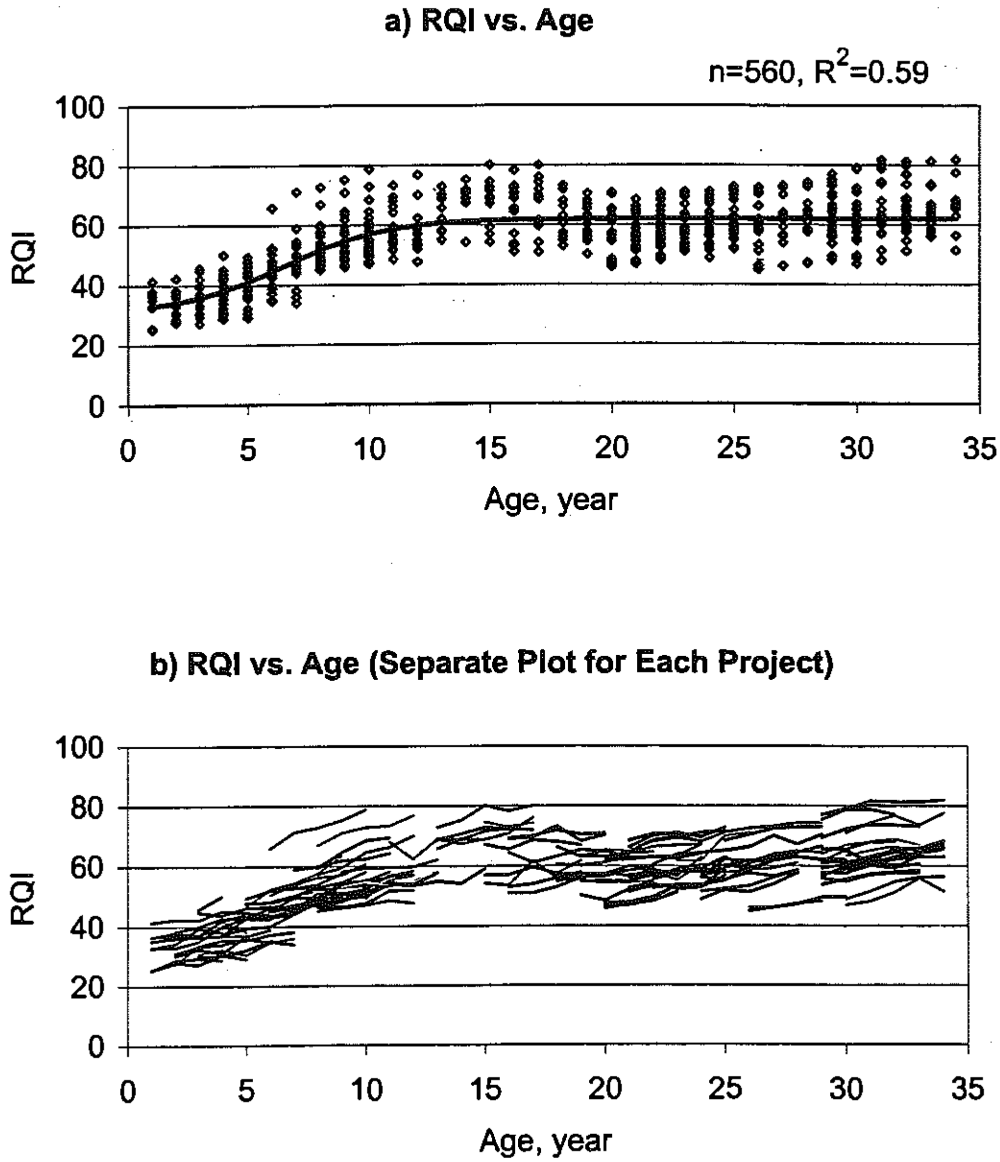


FIGURE C.2 RQI versus Age using 112 Projects - Rigid Pavements

unaccounted for. It should be noted that the data set in this analysis takes into account only major rehabilitation and reconstruction activities, as described in MDOT's 1998 Sufficiency Rating Book. As such, pavement age is defined as the number of years from initial construction or after a major rehabilitation/reconstruction. The data were fitted to a logistic function of the form:

$$RQI = 31 \cdot \frac{e^{(-3.135+0.48Age)}}{1+e^{(-3.135+0.48Age)}} + 30.95$$

Even though this figure has a reasonable R^2 value (0.59), the error is too large to be used for determining the optimal timing of preventive maintenance. The error band is about ± 10. This error corresponds to an error of about ± 7 years in predicted *RSL* since the actual data show that the average increase in RQI per year is about 1.4. Another way to use the master curve is to use the slope of this curve to predict RQI. In Figure C.2, the growth rate from the master curve and the actual RQI growth rates of 112 projects were plotted against pavement age. This figure shows that the slope of this curve, i.e., the growth rate at a given pavement age does not correspond to a real RQI growth rate of an actual pavement section. Because of this, it is difficult to accurately predict RQI growth rates using the master curve. This is because the master curve is a fit of RQI-values from different projects with different ages.

The same analyses were done for composite and flexible pavements. For each pavement type, 100 projects were selected. The criteria for project selection are:

- Minimum project length of 1.0 mile;
- Interstate, US Highway and Michigan Highway
- Age less than 35 years.

The plots of RQI vs. age for composite and flexible pavements are shown in Figures C.3 and C.4, respectively. The equation of the best-fit curve for composite pavements is (R^2=0.56):

$$RQI = 31 \cdot \frac{e^{(-3.7617+0.35Age)}}{1+e^{(-3.7617+0.35Age)}} + 29.50$$

and, for flexible pavements (R^2=0.60):

$$RQI = 159 \cdot \frac{e^{(0.8525+0.10Age)}}{1+e^{(0.8525+0.10Age)}} - 85.65$$

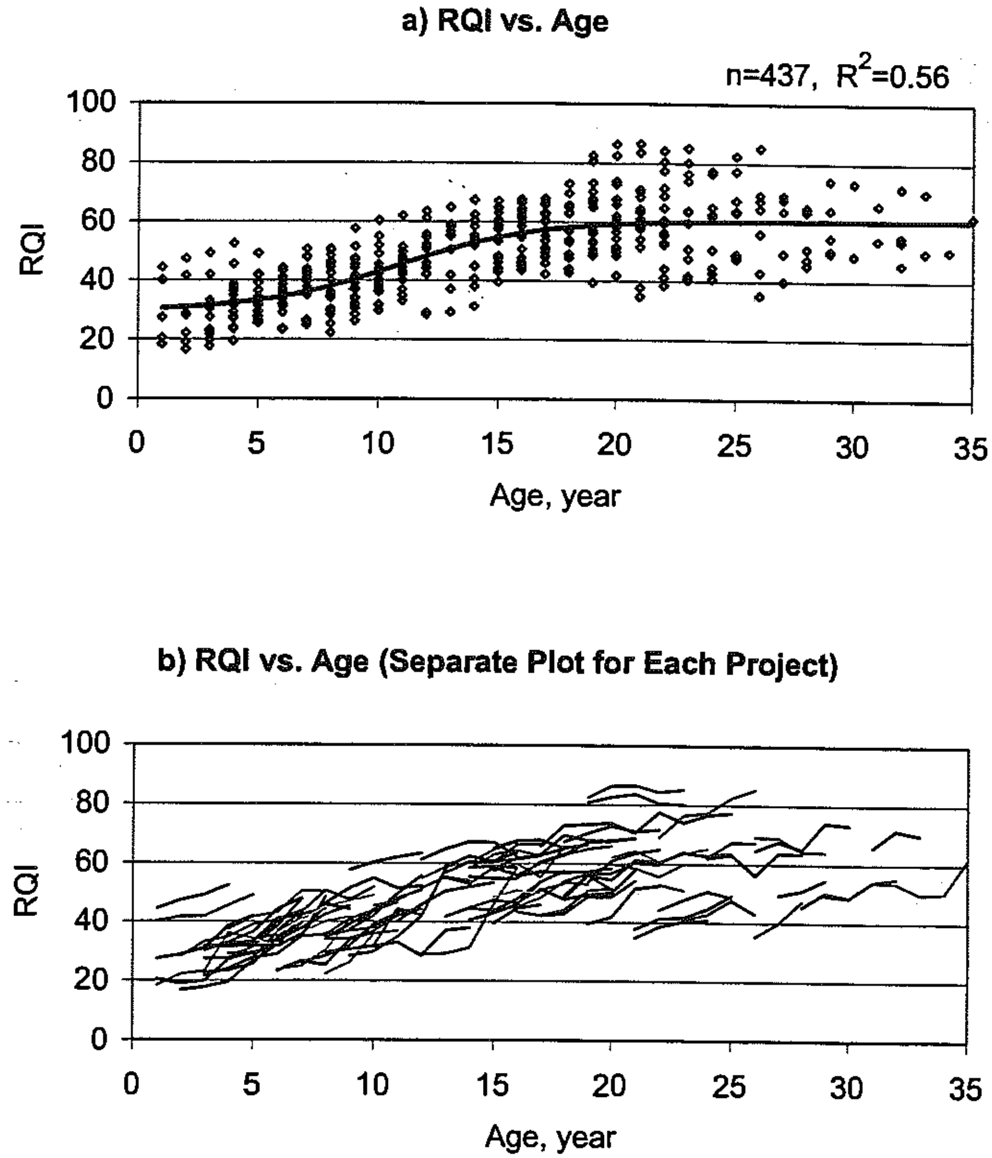


FIGURE C.3 RQI versus Age using 100 Projects - Composite Pavements

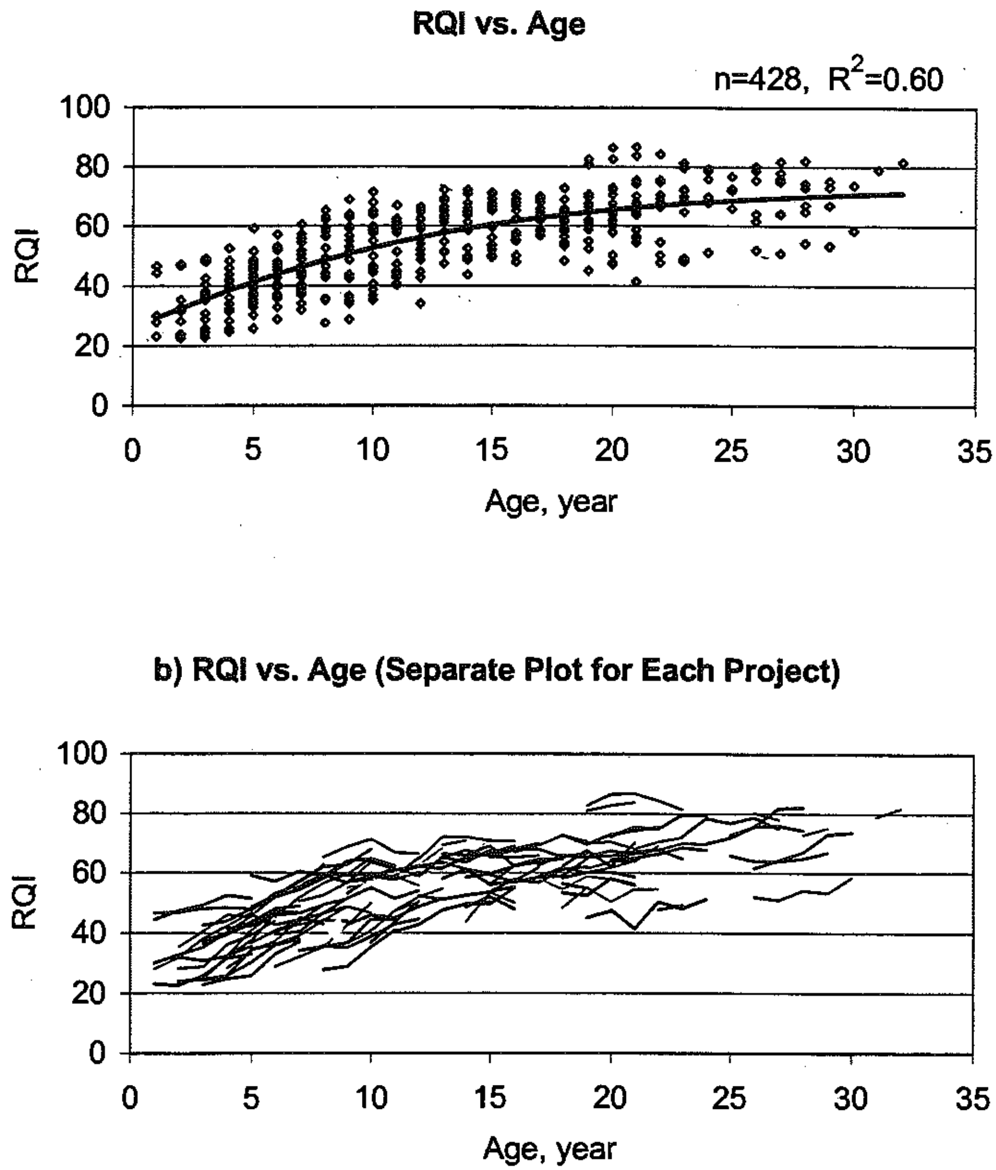


FIGURE C.4 RQI versus Age using 100 Projects - Flexible Pavements

2.3 Model for RQI Growth Rate

In this analysis, the RQI growth rate for each project during the period from 1992 to 1996 (n=112) was calculated using average project RQI-values. These RQI-growth values were plotted against pavement age, as shown in Figure C.5. This figure allows for assigning a RQI growth rate for a given pavement age. The data shows considerable scatter, with an R^2 value of 0.24. The curve fitted to RQI growth rate is a 4^{th} order polynomial:

$$\frac{dRQI}{dAge} = -0.000045 \times Age^4 + 0.0032 \times Age^3 - 0.074 \times Age^2 + 0.6 \times Age + 0.38$$

Using this function and 1992 RQI-values, the 1996 RQI-values for each project were predicted, and the differences between measured and predicted RQI-values were calculated. Dividing these errors by the growth rate obtained from the above model for that age enables errors to be calculated in terms of predicted duration. The distribution of errors in predicted durations are shown in Figure C.6. The reliabilities of the prediction model based on the average RQI for a project length with error ranges of -1.0 to $+1.0$ year and -2.0 to $+2.0$ years are 30% and 72 %, respectively. The same analysis was done for 0.5-mile subsections (n=1382) for all selected projects. The results are shown in Figure C.7. The reliabilities of the prediction model based on RQI values for 0.5-mile sections with error ranges of -1.0 to $+1.0$ year and -2.0 to $+2.0$ years are 28% and 54 %, respectively. The prediction errors in this model are also very large; therefore, it cannot be used to accurately predict RQI growth with time.

3.0 DETERMINING OPTIMAL TIMING FOR SMOOTHING PREVENTIVE MAINTENANCE ACTION

Roughness criticals aimed at minimizing dynamic loads can play an important role in pavement management and preventive maintenance (PM) program. If a PM action, in the form of smoothening the pavement surface, is taken when the RQI critical is reached it could extend the service life of the pavement by several years, since it will reduce roughness-generated dynamic loads.

3.1 Remaining Smooth Period

In order to implement a preventive maintenance strategy using the roughness critical concept developed in this study, it is useful to define a "trigger" value equal to:

$$RQI_{trigger} = RQI_{threshold} - \Delta RQI$$

where $RQI_{trigger}$ represents the trigger-value for planning the smoothing PM action to take plave a few years later.

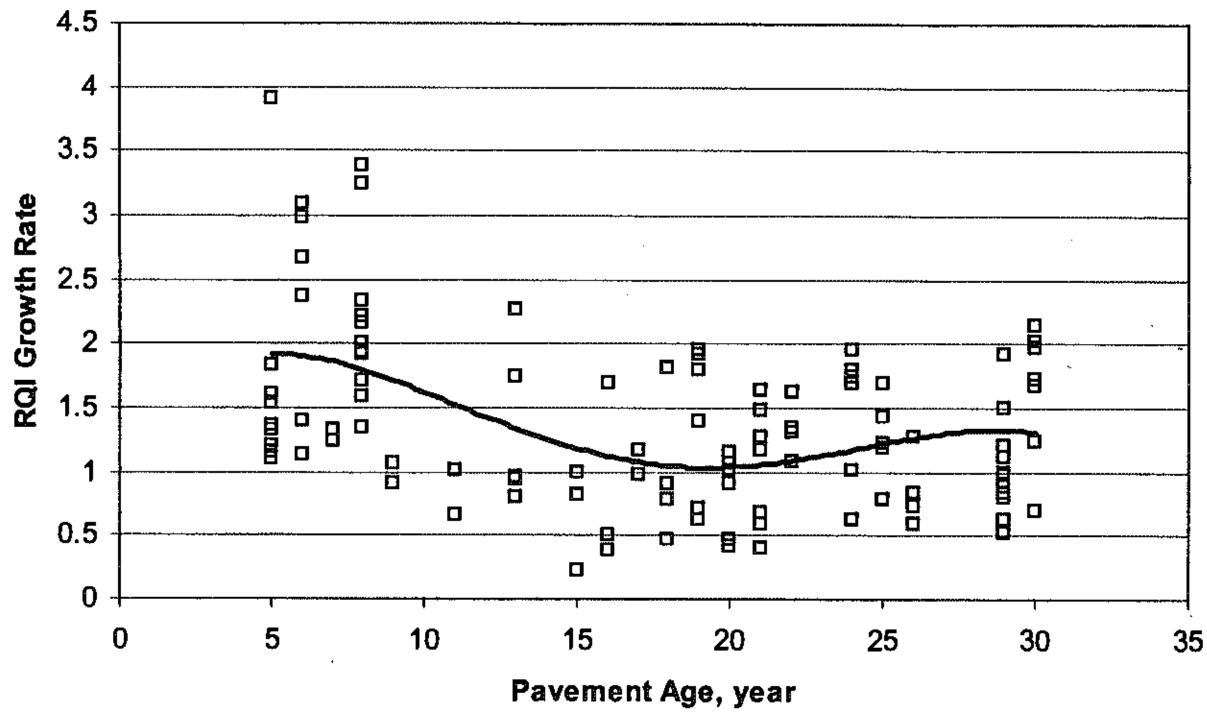


FIGURE C.5 RQI Increase Rate versus Pavement Age

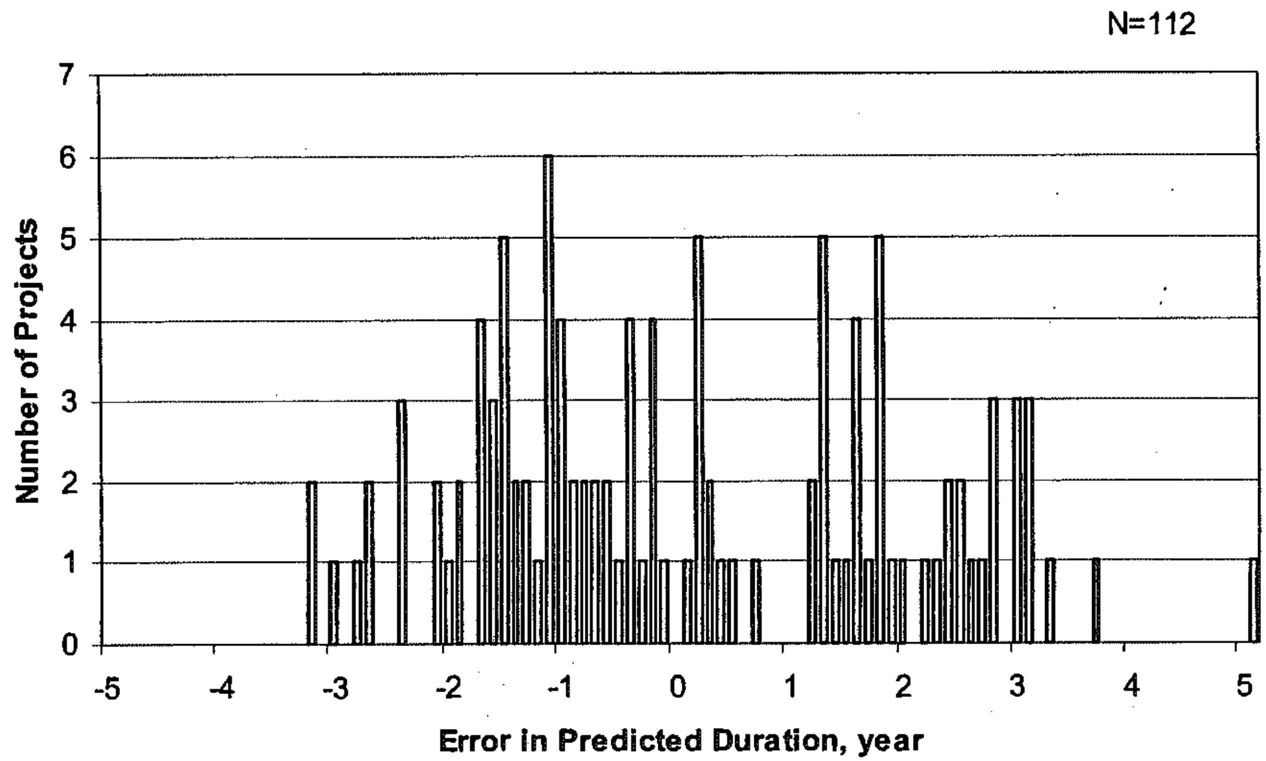


FIGURE C.6 Distribution of Error in Predicted Duration using Project Length

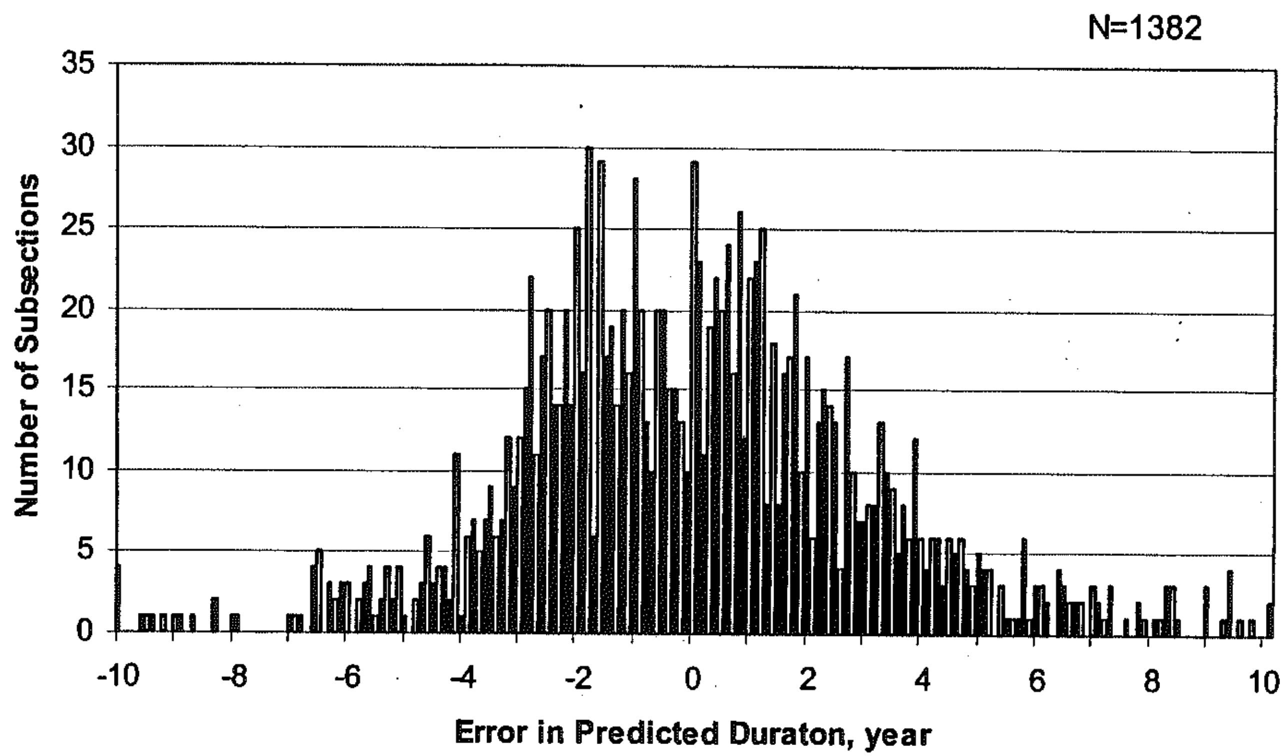


FIGURE C.7 Distribution of Error in Predicted Duration using 0.5-mile

The time (in years) corresponding to ΔRQI can be called the *PM Planning Period (PMP)*. On the other hand, the number of years left to reach the RQI critical, given the current RQI-value is the *Remaining Smooth Period (RSP)*. The RSP is by definition greater than or equal to the PMP. At the trigger RQI-value, the RSP becomes the PMP. Figure C.8 illustrates this concept.

3.2 Reliability for RQI Trigger Value

In order to successfully plan for PM-actions, it is necessary to have a reliable prediction of RQI growth with time. As mentioned in Section 2.2 of this chapter, the RQI growth model described above cannot be used for predicting future RQI because the RQI growth rate at a given pavement age, obtained from that model, is not representative of an individual pavement section. This is so because the curve is an aggregate of many different projects, as opposed to an actual growth curve. In addition, the RQI growth rate model cannot be used for predicting future RQI because of its large prediction error. An alternative (and better) way to interpret the RQI growth data is to use the actual growth rates from each individual pavement section and develop the probability distribution of the RQI growth rate. These results can then be used to calculate the reliability of the PM planning period, PMP, for different $RQI_{trigger}$-values. Figure C.7 shows such plots of the RQI growth rate for 1382 (805-m or 0.5-mile) sections from 112 rigid pavement projects. This figure shows probability distributions of RQI growth rate for 1, 2, 3 and 4 years. The results shown in this figure were used to calculate the reliability that the pavement will not reach the critical RQI-value before *x* years for different $RQI_{trigger}$-values, with *x* being the PM planning period. This is shown in Table C.1. The table shows that the reliability decreases with increasing PM planning period and increasing $RQI_{trigger}$-value. The results show that for a one-year-planning period for PM actions and a desired reliability level of 70% or greater, planning for the smoothing PM action should be triggered at RQI = 61 (R=74.7%). For a two-year-planning period, planning should start at RQI = 60 (R=71.8%). On the other hand, if the desired reliability level is 80% or greater, then planning (for a two-year planning period) should start at RQI = 59 (R=81.6%). The results also show that PM planning periods of 3 or more years are not viable. The above illustration shows that the proposed reliability table would enable MDOT to determine $RQI_{trigger}$-values for the desired PM planning period and reliability level. Similar tables can be developed for isolating potentially important factors such as traffic volume or pavement thickness.

The same analyses were done for composite and flexible pavements using the selected 100 projects for each pavement type. Probability distributions of RQI growth rate for 1, 2, 3 and 4 years are shown in Figures C.10 and C.11 for composite and flexible pavements, respectively. These figures show that one year increase rate in RQI for composite and flexible pavements is around 2. This is higher than that for rigid pavements, which is around 1 (see Figure C.9). This distribution was used to calculate the reliability that the pavement will not reach the critical RQI-value before *x* years for different $RQI_{trigger}$-values, with *x* being the PM planning period. Tables C.2 and C.3 show these reliabilities for composite and flexible pavements, respectively.

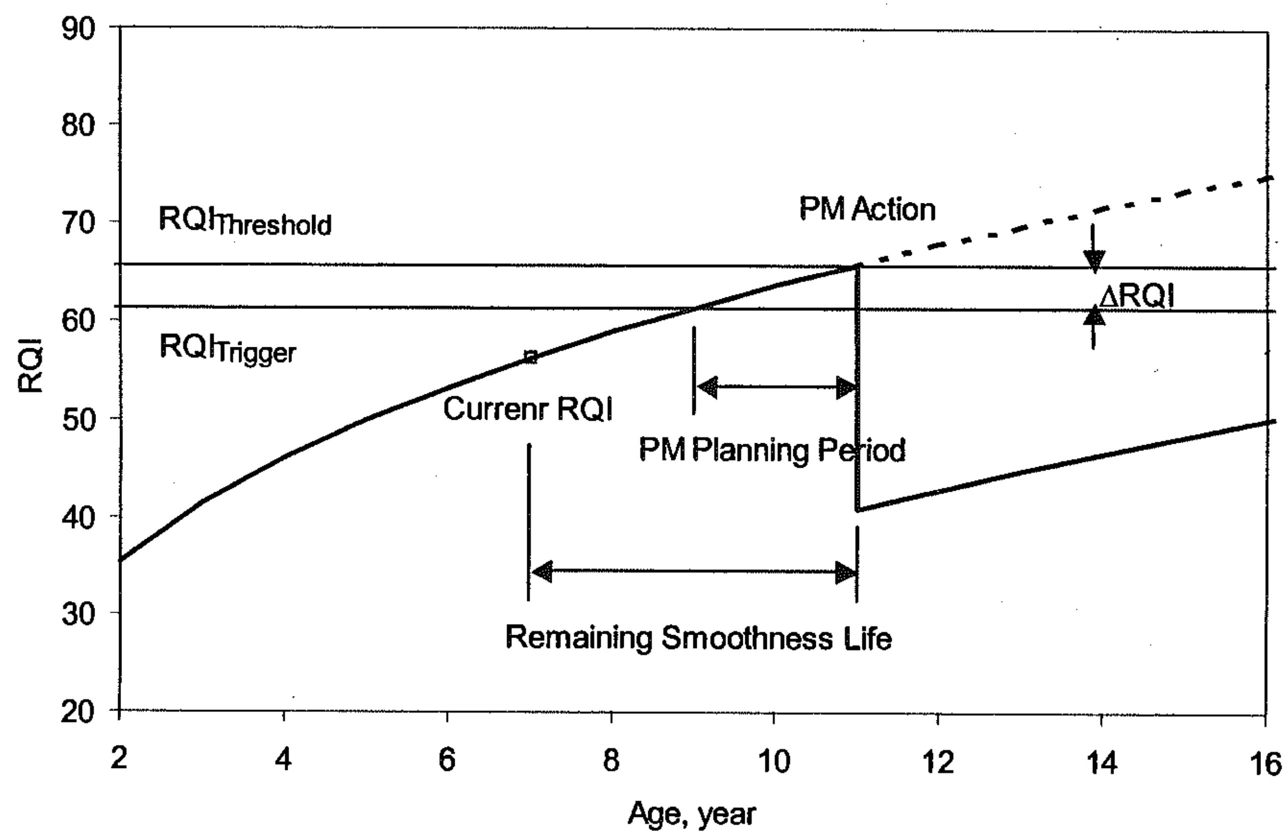


FIGURE C.8 Schematic Figure of 'Remaining Smooth Period' and 'PM Planning Period'

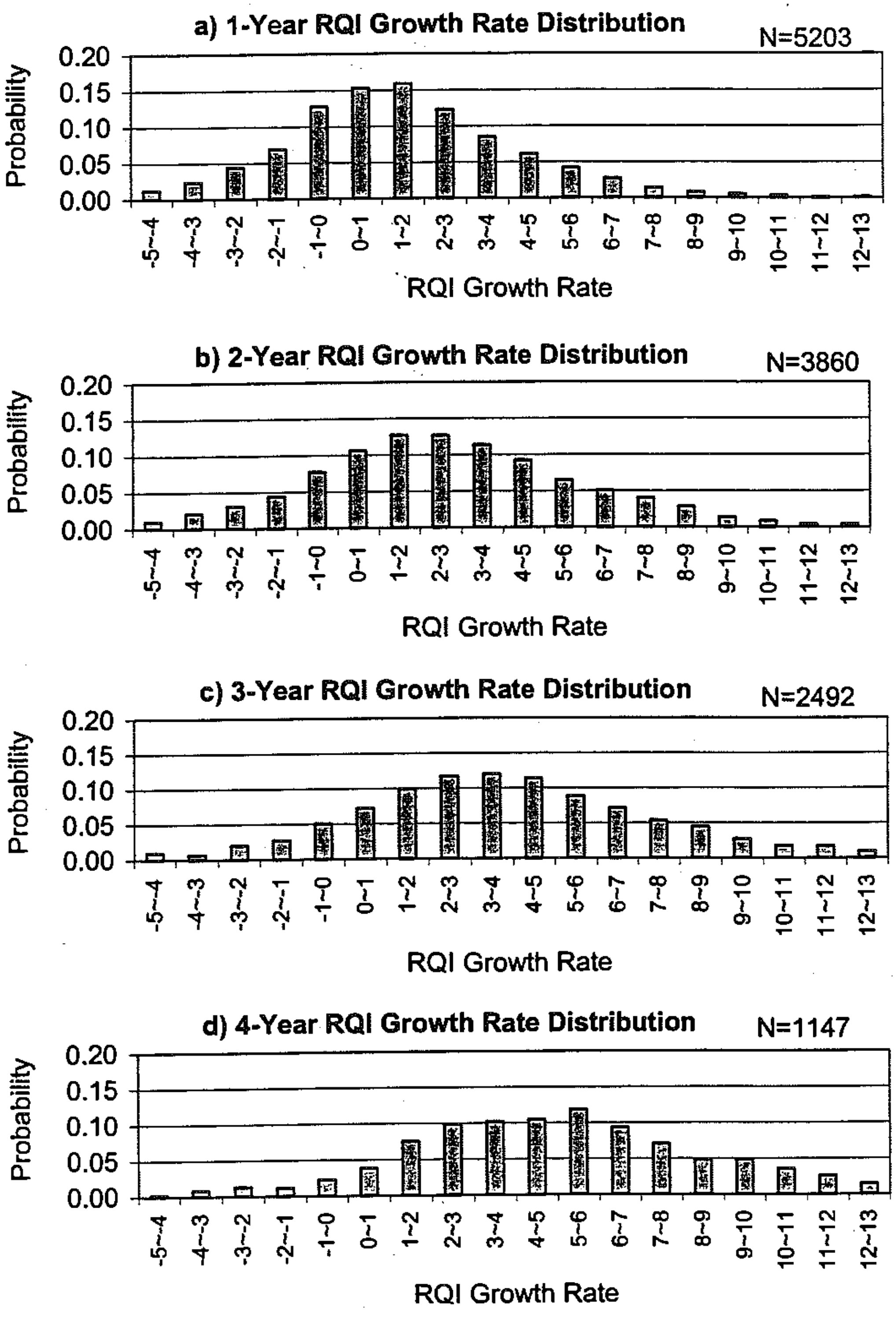


FIGURE C.9 Probability Distribution of RQI Growth Rate for Rigid Pavements

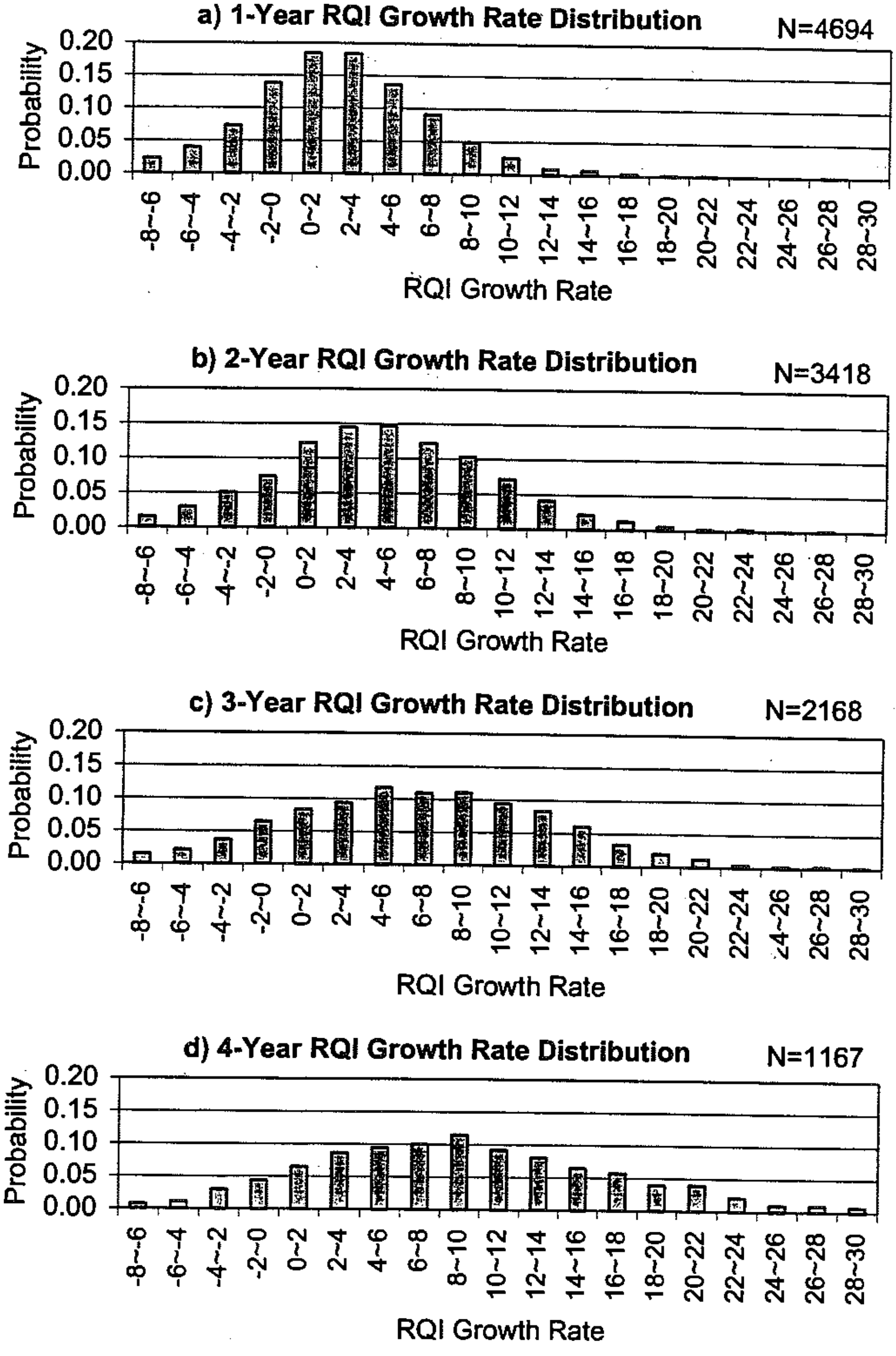


FIGURE C.10 Probability Distribution of RQI Growth Rate for Composite Pavements

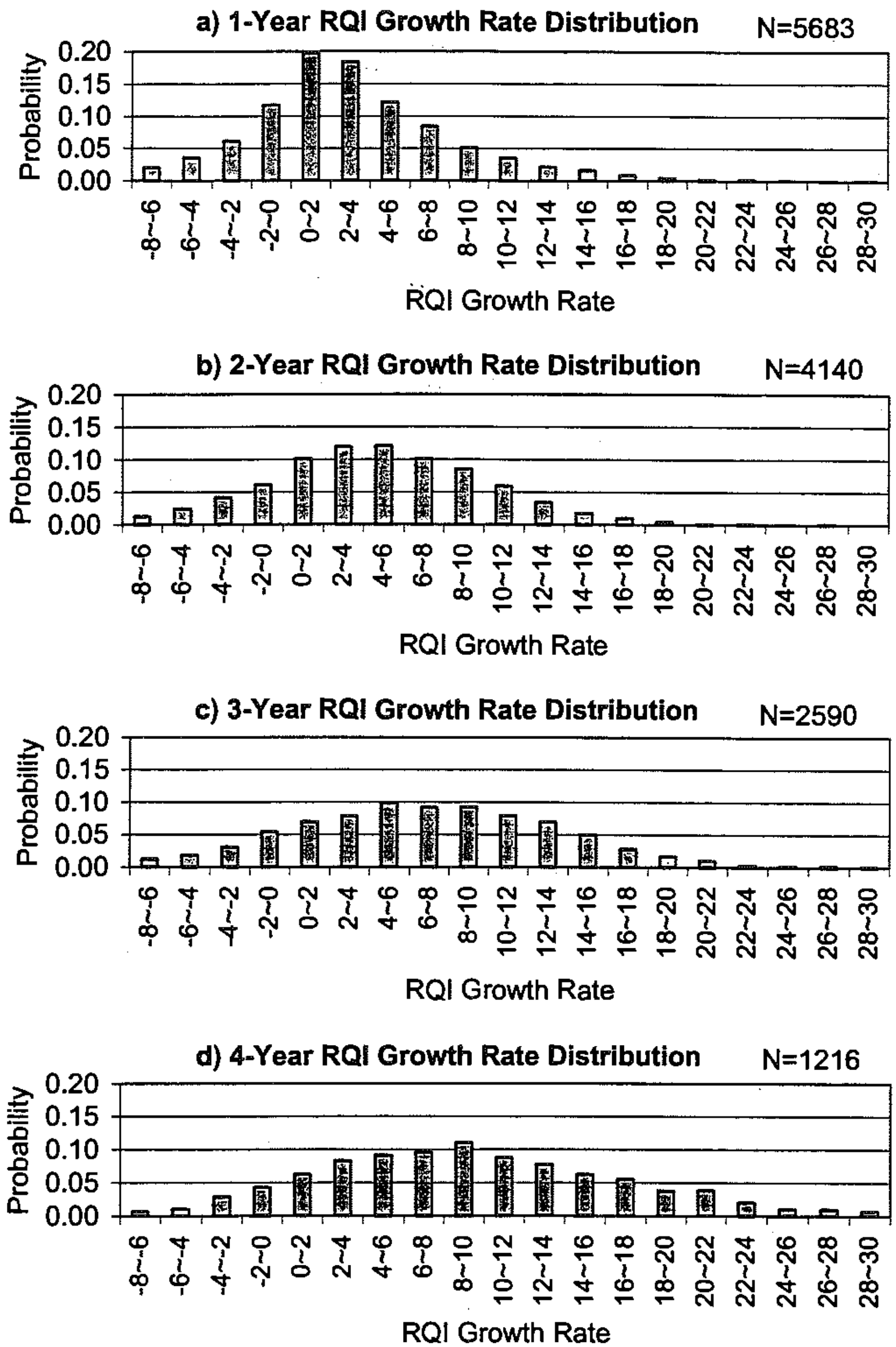


FIGURE C.11 Probability Distribution of RQI Growth Rate for Flexible Pavements

TABLE C.1 Reliability of PM Planning Periods for Different $RQI_{trigger}$-Values for Rigid Pavements

ΔRQI	$RQI_{trigger}$	Reliability			
		PM Planning Period (Years)			
		1	2	3	4
10	45	**99.2**	**97.7**	**93.8**	**86.7**
9	46	**98.7**	**96.4**	**91.1**	**81.8**
8	47	**97.8**	**93.5**	**86.6**	**76.9**
7	48	**96.4**	**89.4**	**81.3**	69.9
6	49	**93.7**	**84.3**	**74.1**	60.6
5	50	**89.5**	**81.6**	65.4	48.7
4	51	**83.3**	**71.8**	53.9	38.2
3	52	**74.7**	59.9	41.9	28.0
2	53	62.4	46.6	30.1	18.1
1	54	46.5	33.2	20.2	10.6

TABLE C.2 Reliability of PM Planning Periods for Different $RQI_{trigger}$-Values for Composite Pavements

ΔRQI	$RQI_{trigger}$	Reliability			
		PM Planning Period (Years)			
		1	2	3	4
10	35	**94.9**	**83.5**	67.6	56.9
9	36	**92.7**	**78.8**	62.1	51.6
8	37	**90.0**	**73.2**	56.6	45.5
7	38	**86.4**	67.5	51.8	40.8
6	39	**80.9**	60.9	45.6	35.5
5	40	**74.6**	53.7	40.5	29.8
4	41	67.3	46.3	33.9	25.9
3	42	58.6	39.1	29.6	20.5
2	43	48.9	31.8	24.4	17.3
1	44	39.2	25.2	19.9	13.9

TABLE C.3 Reliability of PM Planning Periods for Different $RQI_{trigger}$-Values for Flexible Pavements

ΔRQI	$RQI_{trigger}$	Reliability PM Planning Period (Years)			
		1	2	3	4
10	31	**91.0**	**75.7**	59.2	45.1
9	32	**88.6**	**71.1**	52.8	40.0
8	33	**85.8**	65.8	46.1	35.1
7	34	**81.9**	60.7	41.3	30.5
6	35	**77.4**	54.3	36.5	26.0
5	36	**71.7**	48.2	31.9	22.2
4	37	65.2	42.0	27.1	19.1
3	38	56.7	34.8	22.6	15.2
2	39	46.8	28.5	18.7	13.3
1	40	36.3	22.8	15.9	11.3

1396

Development of Roughness Thresholds for the Preventive Maintenance of Pavements based on Dynamic Loading Considerations and Damage Analysis

Karim Chatti, Ph.D.
Doseung Lee, M.S.
Gilbert Y. Baladi, Ph.D., P.E.

PRCE

Michigan State University
Pavement Research Center of Excellence

Final Report – Volume II
June 2001

TESTING AND RESEARCH SECTION
CONSTRUCTION AND TECHNOLOGY DIVISION
RC - 1396 - FINAL REPORT VOLUME II

APPENDICES

APPENDIX D
RQI-DI Relationship

List of Rigid Pavement Sections used for Dynamic Load-Related Distress Analysis
Data Set #1

0<DI<10 RQI<50

Route No.	CS	M.P.	Year
EB I-69	76024	0.0-0.5	93
EB I-69	76024	2.5-3.0	93
EB I-69	76024	3.0-3.5	93
EB I-69	76024	0.0-0.5	95
EB I-69	76024	0.5-1.0	95
EB I-69	76024	1.5-2.0	95
EB I-69	76024	2.5-3.0	95
EB I-69	76024	3.0-3.5	95
EB US-10	18024	3.0-3.5	93
EB US-10	18024	4.0-4.5	93
WB US-10	18024	4.0-4.5	93

0<DI<10 RQI>65

Route No.	CS	M.P.	Year
EB US-2	21022	6.5-7.0	93
EB US-2	21022	8.0-8.5	93
WB US-2	21022	8.0-8.5	93
NB US-31	70014	4.5-5.0	93
NB US-31	70014	4.5-5.0	95
NB US-31	70014	5.0-5.5	95
WB US-2	21025	0.5-1.0	93
WB US-2	21025	5.5-6.0	93
WB I-196	70023	1.0-1.5	94
WB I-196	70023	2.5-3.0	94

10<DI<20 RQI<55

Route No.	CS	M.P.	Year
EB US-10	18024	5.0-5.5	93
EB US-10	18024	5.5-6.0	93
EB US-10	18024	6.0-6.5	93
WB US-10	18024	2.5-3.0	93
WB US-10	18024	4.5-5.0	93
WB US-10	18024	4.5-5.0	95
EB US-2	21025	1.0-1.5	93
EB US-2	21025	2.5-3.0	93
EB US-2	21025	1.0-1.5	95
EB US-2	21025	2.0-2.5	95
EB US-2	21025	2.5-3.0	95
WB US-2	21025	4.5-5.0	93
WB US-2	21025	1.5-2.0	95
WB US-2	21025	2.0-2.5	95
WB US-2	21025	2.5-3.0	95
WB US-2	21025	4.0-4.5	95
WB US-2	21025	4.5-5.0	95

List of Rigid Pavement Sections used for Dynamic Load-Related Distress Analysis
Data Set #1(Continued)

10<DI<20 RQI>70

Route No.	CS	M.P.	Year
EB I-94	11017	2.5-3.0	93
EB I-94	11017	4.0-4.5	93
EB I-94	11017	1.5-2.0	95
WB I-196	70023	1.5-2.0	94
WB I-196	70023	2.0-2.5	94
WB I-196	70023	3.0-3.5	94
WB I-196	70023	4.0-4.5	94
WB I-196	70023	1.0-1.5	96
WB I-196	70023	1.5-2.0	96
WB I-196	70023	2.0-2.5	96
WB I-196	70023	3.0-3.5	96
WB I-196	70023	3.5-4.0	96
WB I-196	70023	4.0-4.5	96
NB US-24	63031	0.0-0.5	92
WB US-2	21025	0.0-0.5	93
WB US-2	21025	5.0-5.5	93
WB US-2	21025	0.0-0.5	95

20<DI<30 RQI<65

Route No.	CS	M.P.	Year
WB US-10	18024	2.5-3.0	95
WB US-10	18024	5.0-5.5	95
WB US-10	18024	7.0-7.5	95
WB US-2	21025	1.0-1.5	95

10<DI<20 RQI>80

Route No.	CS	M.P.	Year
EB I-94	11017	3.5-4.0	93
EB I-94	11017	5.0-5.5	93
EB I-94	11017	1.0-1.5	95
WB US-2	21022	5.5-6.0	93

30<DI<40 RQI<60

Route No.	CS	M.P.	Year
EB US-10	18024	3.0-3.5	95
EB US-10	18024	3.5-4.0	95
EB US-10	18024	6.0-6.5	95
WB US-10	18024	5.5-6.0	95

List of Rigid Pavement Sections used for Dynamic Load-Related Distress Analysis
Data Set #1(Continued)

30<DI<40 RQI>75

Route No.	CS	M.P.	Year
EB I-94	11017	3.5-4.0	95
EB I-94	11017	5.0-5.5	95
WB I-196	70023	0.0-0.5	94
WB I-196	70023	0.0-0.5	96

List of Composite Pavement Sections used for Dynamic Load-Related Distress Analysis
Data Set #1

10<DI<20 RQI<40

Route No.	CS	M.P.	Year
EB I-94	38101	2.5-3.0	93
EB I-94	38101	3.0-3.5	93
EB I-94	38101	3.5-4.0	93
EB I-94	38101	5.5-6.0	93
EB I-94	38101	7.5-8.0	93
EB I-94	38101	8.0-8.5	93
M-21	76062	3.5-4.0	94
M-21	76062	5.0-5.5	94
M-21	76062	5.5-6.0	94

10<DI<20 RQI<55

Route No.	CS	M.P.	Year
NB US-127	38131	0.0-0.5	93
NB US-127	38131	0.0-0.5	95
NB US-127	38131	2.5-3.0	95
WB US-2	21022	0.0-0.5	95
WB US-2	21022	0.5-1.0	95
WB US-2	21022	1.0-1.5	95
WB US-2	21022	1.5-2.0	95
M-52	76012	7.5-8.0	94

20<DI<30 RQI<40

Route No.	CS	M.P.	Year
EB I-94	38101	1.5-2.0	93
NB US-127	38131	2.0-2.5	93
M-95	22012	13.5-14.0	94
M-21	76062	4.0-4.5	94
M-21	76062	4.5-5.0	94

20<DI<30 RQI>60

Route No.	CS	M.P.	Year
M-52	76012	5.5-6.0	96
M-52	76012	7.0-7.5	96
M-52	76012	7.5-8.0	96
M-95	22012	14.0-14.5	96

30<DI<40 RQI<45

Route No.	CS	M.P.	Year
SB US-131	78012	0.5-1.0	95
SB US-131	78012	1.5-2.0	95
M-95	22012	10.5-11.0	92
M-95	22012	11.0-11.5	94
M-95	22012	12.5-13.0	94

List of Composite Pavement Sections used for Dynamic Load-Related Distress Analysis
Data Set #1 (Continued)

30<DI<40 RQI>60

Route No.	CS	M.P.	Year
M-95	22012	11.0-11.5	96
M-95	22012	13.0-13.5	96
M-95	22012	13.5-14.0	96
M-21	76062	3.0-3.5	96
M-115	18011	3.5-4.0	94
M-115	18011	6.0-6.5	94
M-115	18011	3.5-4.0	96

40<DI<50 RQI<55

Route No.	CS	M.P.	Year
SB US-131	78012	1.0-1.5	95
SB US-131	78012	7.5-8.0	95
M-21	76062	10.0-10.5	96
M-21	76062	11.0-11.5	96

40<DI<50 RQI>62

Route No.	CS	M.P.	Year
SB US-131	78012	6.5-7.0	95
SB US-131	78012	8.5-9.0	95
M-21	76062	8.0-8.5	96
M-95	22012	12.5-13.0	96

List of Flexible Pavement Sections used for Dynamic Load-Related Distress Analysis
Data Set #1

10<DI<20 RQI<35

Route No.	CS	M.P.	Year
EB I-96	33084	16.5-17.0	95
M-30	26032	1.0-1.5	92
M-30	26032	1.5-2.0	92
M-30	26032	6.0-6.5	92
M-30	26032	6.5-7.0	92
M-30	26032	8.0-8.5	92
M-30	26032	8.5-9.0	92
M-28	31021	1.0-1.5	93
M-28	31021	6.0-6.5	93
M-28	31021	7.5-8.0	93
M-57	25102	6.5-7.0	92
M-57	25102	9.0-9.5	92

10<DI<20 RQI>55

Route No.	CS	M.P.	Year
M-36	47041	14.5-15.0	92
M-36	47041	15.0-15.5	92
M-36	47041	17.0-17.5	92
M-36	47041	17.5-18.0	92
M-36	47041	18.0-18.5	92
M-36	47041	18.5-19.0	92
M-36	47041	20.5-21.0	92
M-65	35012	7.5-8.0	94

20<DI<30 RQI<40

Route No.	CS	M.P.	Year
EB US-10	09101	1.5-2.0	95
M-28	31021	2.0-2.5	93
M-28	31021	3.5-4.0	93
M-28	31021	8.5-9.0	93
M-57	29022	8.5-9.0	96

20<DI<30 RQI<60

Route No.	CS	M.P.	Year
NB US-23	47041	15.5-16.0	92
NB US-23	47041	16.5-17.0	92
NB US-23	47041	21.5-22.0	92
M-95	22013	8.5-9.0	94

List of Flexible Pavement Sections used for Dynamic Load-Related Distress Analysis
Data Set #1 (Continued)

30<DI<40 RQI<40

Route No.	CS	M.P.	Year
EB US-10	09101	2.0-2.5	95
EB US-10	09101	3.5-4.0	95
EB US-10	09101	4.0-4.5	95
EB US-10	09101	4.5-5.0	95
NB US-27	72014	7.5-8.0	93
M-57	29022	6.5-7.0	96
M-57	29022	8.0-8.5	96
M-57	25102	1.5-2.0	92
M-28	31021	8.0-8.5	93

30<DI<40 RQI>60

Route No.	CS	M.P.	Year
NB US-27	72014	7.0-7.5	95
M-95	22013	3.5-4.0	92
M-95	22013	9.0-9.5	92
M-95	22013	2.5-3.0	94

40<DI<50 RQI<40

Route No.	CS	M.P.	Year
EB US-10	09101	2.5-3.0	95
EB US-10	09101	3.0-3.5	95
M-30	26032	16.0-16.5	92
M-57	29022	2.0-2.5	96
M-57	29022	7.5-8.0	96
M-57	25102	2.0-2.5	92

40<DI<50 RQI>60

Route No.	CS	M.P.	Year
M-36	47041	20.0-20.5	92
M-95	22013	9.0-9.5	94

50<DI<60 RQI<40

Route No.	CS	M.P.	Year
M-28	31021	8.0-8.5	95
M-57	29022	2.5-3.0	96

50<DI<60 RQI>60

Route No.	CS	M.P.	Year
M-95	22013	11.5-12.0	92
M-95	22013	3.5-4.0	94
M-95	22013	4.0-4.5	94
M-95	22013	6.5-7.0	94
M-65	35012	13.5-14.0	96
M-65	35012	15.0-15.5	96

List of Rigid Pavement Sections used for Dynamic Load-Related Distress Analysis
Data Set #2 and 3

0<DI<10 RQI<50

Route No.	CS	M.P.	Year
NB I-75	06111	6.0-6.5	95
NB I-75	06111	11.0-11.5	95
NB I-75	09035	17.0-17.5	93
NB I-75	09035	3.0-3.5	95
WB I-94	39022	11.0-11.5	95
EB I-69	44044	1.5-2.0	95
NB US-131	59012	1.0-1.5	93
NB US-131	59012	9.0-9.5	93
WB I-96	82122	6.5-7.0	93
WB I-96	82122	8.0-8.5	95

0<DI<10 RQI>66

Route No.	CS	M.P.	Year
NB I-75	09035	0.0-0.5	93
NB I-75	09035	5.5-6.0	93
NB I-75	09035	0.0-0.5	95
NB I-75	09035	1.0-1.5	95
NB I-75	09035	14.5-15.0	95
NB I-75	09035	22.0-22.5	95
WB I-69	25084	7.5-8.0	93
WB I-69	25084	9.5-10.0	93
WB I-69	25084	10.0-10.5	93
EB I-94	80023	12.5-13.0	93
EB I-94	80023	13.0-13.5	93
WB I-94	82122	95.-10.0	93

10<DI<20 RQI<55

Route No.	CS	M.P.	Year
NB I-75	06111	9.5-10.0	95
NB I-75	06111	13.0-13.5	95
NB I-75	06111	14.0-14.5	95
NB I-75	06111	14.5-15.0	95
NB I-75	06111	16.0-16.5	95
NB I-75	09035	14.0-14.5	93
NB US-131	59012	1.5-2.0	93
NB US-131	59012	3.0-3.5	93
WB I-94	82122	5.5-6.0	93
WB I-94	82122	6.0-6.5	93
WB I-94	82122	5.5-6.0	95
WB I-94	82122	6.0-6.5	95
WB I-94	82122	6.5-7.0	95
WB I-94	82122	7.0-7.5	95

List of Rigid Pavement Sections used for Dynamic Load-Related Distress Analysis
Data Set #2 and 3 (Continued)

10<DI<20 RQI>77

Route No.	CS	M.P.	Year
EB I-94	50122	0.0-0.5	93
EB I-94	50122	3.0-3.5	93
EB I-94	50122	4.0-4.5	93
EB I-94	80023	9.0-9.5	95
NB US-23	81076	1.5-1.0	93
NB US-23	81076	1.0-1.5	93
NB US-23	81076	1.5-2.0	93
NB US-23	81076	2.0-2.5	93
NB US-23	81076	2.5-3.0	93
NB US-23	81076	3.0-3.5	93
NB US-23	81076	3.5-4.0	93
NB US-23	81076	4.0-4.5	93

20<DI<30 RQI<63

Route No.	CS	M.P.	Year
NB I-69	12034	2.0-2.5	93
NB I-69	12034	2.0-2.5	95
SB I-69	23061	13.0-13.5	93
SB I-69	23061	13.0-13.5	95
NB US-131	59012	2.0-2.5	93
WB I-96	82122	5.0-5.5	95
WB I-96	82122	9.5-10.0	95
WB I-96	82122	10.0-10.5	95

20<DI<30 RQI>80

Route No.	CS	M.P.	Year
EB I-69	44043	0.5-1.0	93
EB I-94	50122	1.5-2.0	93
EB I-94	50122	2.5-3.0	93
NB US-23	81076	4.5-5.0	93
NB US-23	81076	5.0-5.5	93
NB US-23	81076	5.5-6.0	93

30<DI<40 RQI<70

Route No.	CS	M.P.	Year
NB I-69	12034	0.5-1.0	93
NB I-69	12034	8.5-9.0	93
SB I-69	23061	7.5-8.0	93
SB I-69	23061	9.0-9.5	95
WB I-96	82122	3.5-4.0	95

List of Rigid Pavement Sections used for Dynamic Load-Related Distress Analysis Data Set #2 and 3 (Continued)

30<DI<40 RQI>80

Route No.	CS	M.P.	Year
EB I-94	50122	5.5-6.0	93
EB I-94	50122	1.1-1.5	95
EB I-94	50122	1.5-2.0	95
EB I-94	50122	2.0-2.5	95
EB I-94	50122	2.5-3.0	95

List of Composite Pavement Sections used for Dynamic Load-Related Distress Analysis
Data Set #2 and 3

10<DI<20 RQI<40

Route No.	CS	M.P.	Year
NB I-75	73111	3.5-4.0	93
NB I-75	73111	1.5-2.0	95
NB I-75	73111	8.0-8.5	95
EB US-12	81063	0.5-1.0	93
US-41	55011	7.0-7.5	96
US-41	55011	4.0-4.5	96
US-41	55011	16.0-16.5	96
US-41	55011	5.0-5.5	96
US-41	55011	4.5-5.0	96
US-41	55011	15.5-16.0	96

10<DI<20 RQI>55

Route No.	CS	M.P.	Year
NB I-75	25131	2.0-2.5	93
NB I-75	25131	0.0-0.5	95
NB I-75	25131	0.5-1.0	95
NB I-75	63173	5.0-5.5	95
NB I-75	63173	9.5-10.0	93
NB I-75	63173	0.0-0.5	93
NB I-75	63173	10.0-10.5	95
NB I-75BL	63091	1.5-2.0	93
NB I-75BL	63091	1.0-1.5	93
WB US-10	53022	0.5-1.0	93
WB US-10	53022	8.0-8.5	93
US-23	06075	4.5-5.0	93
US-23	06075	7.5-8.0	93
US-23	06075	1.5-2.0	93
US-23	06075	9.0-9.5	93

20<DI<30 RQI<45

Route No.	CS	M.P.	Year
NB I-75	25131	2.5-3.0	95
WB US-2	49022	7.5-8.0	95
US-41	55011	3.5-4.0	96
US-41	55011	14.5-15.0	96
US-41	55011	15.0-15.5	96

List of Composite Pavement Sections used for Dynamic Load-Related Distress Analysis Data Set #2 and 3 (Continued)

20<DI<30 RQI<60

Route No.	CS	M.P.	Year
EB I-94	81104	4.0-4.5	95
EB I-94	81104	5.0-5.5	95
EB I-94BL	38083	4.5-5.0	92
WB US-10	53022	0.0-0.5	93
US-23	06072	6.5-7.0	93
US-23	06072	8.5-9.0	93
US-127	46011	1.0-1.5	93
US-127	46011	1.5-2.0	93
US-127	46011	2.0-2.5	93

30<DI<40 RQI<50

Route No.	CS	M.P.	Year
NB I-75	63173	0.0-0.5	95
NB I-75	63173	2.5-3.0	95
WB US-2	49022	2.0-2.5	95
WB US-2	49022	4.0-4.5	95
WB US-2	49022	5.5-6.0	95
WB US-10	53022	5.0-5.5	95

30<DI<40 RQI>65

Route No.	CS	M.P.	Year
EB I-94	81104	3.5-4.0	95
EB I-94BL	38083	3.5-4.0	92
US-23	06072	7.0-7.5	93
US-31	10031	4.5-5.0	95
M-50	58032	3.0-3.5	92

40<DI<50 RQI<60

Route No.	CS	M.P.	Year
NB I-75	63173	1.0-1.5	95
NB I-75	63173	1.5-2.0	95
WB US-10	53022	6.0-6.5	95
WB US-2	49022	7.0-7.5	95
WB US-2	49022	12.0-12.5	95
US-31	10031	3.5-4.0	95
M-50	58032	2.0-2.5	92
M-50	58032	4.5-5.0	92
M-50	58032	5.0-5.5	92

List of Composite Pavement Sections used for Dynamic Load-Related Distress Analysis Data Set #2 and 3 (Continued)

40<DI<50 RQI<68

Route No.	CS	M.P.	Year
EB I-94BL	38083	4.5-5.0	94
M-18	26011	3.5-4.0	92
M-50	58032	0.0-0.5	92
M-50	58032	1.0-1.5	92

List of Flexible Pavement Sections used for Dynamic Load-Related Distress Analysis
Data Set #2 and 3

10<DI<20 RQI<25

Route No.	CS	M.P.	Year
SB US-131	54014	4.0-4.5	93
SB US-131	54014	5.0-5.5	93
SB US-131	54014	5.5-6.0	93
SB US-131	54014	6.5-7.0	93
SB US-131	54014	7.0-7.5	93
NB US-131	67016	0.5-1.0	93
NB US-131	67016	1.5-2.0	93
NB US-131	67016	2.5-3.0	93
NB US-131	67016	3.0-3.5	93
NB US-131	67016	3.5-4.0	93
NB US-131	67016	4.0-4.5	93
NB US-131	67016	5.0-5.5	93

10<DI<20 RQI>45

Route No.	CS	M.P.	Year
SB US-131	54014	0.5-1.0	93
SB US-131	54014	8.0-8.5	93
SB US-131	54014	0.0-0.5	95
SB US-131	54014	0.5-1.0	95
SB US-131	54014	11.5-12.0	95
NB US-131	67016	5.0-5.5	95
M-52	33091	2.0-2.5	92
M-52	33091	6.0-6.5	92
M-52	81013	0.0-0.5	96
M-53	81013	1.5-2.0	96
M-54	81013	2.0-2.5	96
M-55	81013	3.5-4.0	96
M-56	81013	4.5-5.0	96

20<DI<30 RQI<40

Route No.	CS	M.P.	Year
NB US-27	20016	2.5-3.0	93
NB US-27	20016	3.0-3.5	93
NB US-31	61074	1.0-1.5	93
NB US-31	70016	1.5-2.0	93
SB US-131	54014	3.5-4.0	93
SB US-131	54014	6.0-6.5	93
SB US-131	54014	7.5-8.0	93
SB US-131	54014	5.0-5.5	95
M-30	56032	3.5-4.0	96
M-52	33091	4.5-5.0	92

List of Flexible Pavement Sections used for Dynamic Load-Related Distress Analysis
Data Set #2 and 3 (Continued)

20<DI<30 RQI>55

Route No.	CS	M.P.	Year
NB I-196	11111	0.0-0.5	93
NB I-196	11111	4.5-5.0	93
NB I-196	11111	5.5-5.5	93
NB US-27	20016	3.0-3.5	95
NB US-27	20016	4.0-4.5	95
M-28	66021	0.0-0.5	92
M-28	66021	0.5-1.0	92
NB US-31	70016	1.0-1.5	95
NB I-196	80012	5.5-6.0	93
NB I-196	80012	6.0-6.5	93
NB I-196	80012	7.0-7.5	93

30<DI<40 RQI<40

Route No.	CS	M.P.	Year
EB I-94	11015	0.0-0.5	95
EB I-94	11015	0.5-1.0	95
EB I-94	11015	1.0-1.5	95
EB I-94	11015	1.5-2.0	95
NB US-27	20016	1.5-2.0	93
NB US-27	20016	2.0-2.5	93
SB US-131	54014	2.5-3.0	93
SB US-131	54014	3.0-3.5	93
SB US-131	54014	4.0-4.5	95
SB US-131	54014	4.5-5.0	95
SB US-131	54014	5.0-5.5	95
M-52	33091	5.5-6.0	92

30<DI<40 RQI>62

Route No.	CS	M.P.	Year
EB I-94	11111	0.5-1.0	93
EB I-94	11111	1.0-1.5	93
EB I-94	11111	1.5-2.0	93
EB I-94	11111	3.0-3.5	93
EB I-94	11111	3.5-4.0	93
EB I-94	11111	6.5-7.0	93
NB US-27	20016	0.5-1.0	93
NB US-27	20016	4.5-5.0	95
SB US-131	54014	8.5-9.0	93
M-28	66021	0.0-0.2	93
M-35	21032	17.5-18.0	94
M-35	21032	19.5-20.0	94

List of Flexible Pavement Sections used for Dynamic Load-Related Distress Analysis Data Set #2 and 3 (Continued)

40<DI<50 RQI<55

Route No.	CS	M.P.	Year
SB US-131	54014	3.5-4.0	95
M-20	54021	3.0-3.5	96
M-30	56032	4.0-4.5	96
M-28	66021	3.5-4.0	92
M-28	66021	4.0-4.5	92
M-28	66021	6.5-7.0	92
M-28	66021	1.5-2.0	93
M-28	66021	2.0-2.5	93
M-52	33091	3.5-4.0	96
M-52	33091	5.5-6.0	96

40<DI<50 RQI<66

Route No.	CS	M.P.	Year
EB I-94	11111	2.0-2.5	93
EB I-94	11111	2.5-3.0	93
EB I-94	11111	4.0-4.5	93
NB I-196	80012	5.0-5.5	93
NB I-196	80012	6.5-7.0	93
NB US-27	20016	5.0-5.5	93
M-35	21032	17.0-17.5	94
M-35	21032	18.0-18.5	94
M-28	66021	0.0-0.5	95

DI, DP and RQI Data for Rigid Pavements (Continued)

CS-09035

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0	8.25	9.675	20.725	4.051715	4.587908	67.5	69.5	71.25	77.25	79
0.5	10.775	4.28	14.98	2.935935	2.284903	71	70.75	73.75	74.75	77.2
1	6.38	7.28	17.14	3.721243	2.860452	62.6	64.4	65	68.6	72.4
1.5	4.02	8.35	9.52	2.46	3.29	57.5	60.75	64.5	56.66667	60.33333
2	7.1	8.7	16.54	4.696	4.222	58.4	55	58	60	61.2
2.5	5.14	6.28	14.14	3.434	3.926	60.2	61.2	58.6	61.8	62.2
3	2.675	5.3	11.3	2.541763	2.556159	55.25	52.75	51.25	49.66667	54
3.5	3.175	10.775	15.225	2.235	2.518	54.25	54.25	57.25	55.75	60.75
4	3.94	10.8	14.6	2.164	1.742	60	59.8	60.2	63	62.8
4.5	5.46	11.08	15.68	2.77	3.484	61.6	61.4	62.4	60.6	66
5	5.2	13.28	16.64	3.726	3.69	56.8	60.4	66.6	63	65.4
5.5	6.28	10.64	15.88	3.296	1.276	61	67.2	65.6	65.8	65.8
6	6.375	9.45	12.74	4.430833	4.132273	56.75	60.5	65.75	59	64.75
6.5	5.34	9.1	11.14	2.876	3.51	52.8	53.6	53.8	55.2	58.4
7	1.74	3.66	9.24	1.142	0.846	42.8	44.2	45	44.4	48
7.5	2.08	4.42	12.12	0.788	0.638	44.8	48.2	43.25	49.2	51.2
8	5.55	7.825	11.4	4.093553	4.163816	52.25	50.75	55.33333	52	55
8.5	5.24	6.1	14.12	5.004	4.654	52	54.4	55.2	55.75	58.4
9	10.78	11.32	19.06	10.084	10.438	60	66.8	65.2	71.66667	62.8
9.5	6.74	7.94	16.34	6.45	6.59	54.6	63.8	66.4	59.4	63
10	5.8	6.28	13.78	5.192	4.664	52.6	53.4	55.4	56.6	61.4
10.5	5.8	6.38	13.92	5.38	5.096	55.6	56.2	57.4	56.8	62.6
11	7.82	8.2	20.82	6.15	6.472	60.2	59.2	60.2	60	63
11.5	14.82	15.46	27.58	13.67	13.346	63.2	71.6	73.6	71.2	73.8
12	10.12	9.78	15.16	9.024	7.576	58.2	59.4	62.6	59.8	65.6
12.5	1.54	3.66	5.92	1.414	1.072	53.8	53.4	53.4	50.8	54.4
13	3.7	6.9	12.26	3.004	2.838	52.4	52.8	53.2	56	56.6
13.5	17.8	12.6	22	14.916	11.7675	59.4	63.4	69.4	63.2	67.2
14	10.3	9.16	15.76	10.1	8.394	51.8	54	56.6	60	63.6
14.5	10.3	9.5	18.5	9.51	8.936	61.8	61.4	62.6	66.2	66.2
15	12.6	11.125	18.65	11.05	9.823322	60.25	61.75	64.75	67	72.33333

CS-09035

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
15.5	8.02	8.4	18.48	6.396	6.096	55.6	60	57.4	60	62.8
16	5	7.14	13.8	3.822	4.872	52.6	56.6	56.4	61	60.2
16.5	6.1	7.72	15	5.594	6.504	53.4	59	55.8	56.2	62
17	7.16	7.28	13.98	6.812	6.08	46.8	48.8	52.4	55.4	62.8
17.5	7.72	9.06	16.06	7.124	6.902	53.8	51.6	61.2	65.4	63
18	12.86	13.86	21.18	11.57733	10.458	57.4	61.8	67.4	66.2	66.8
18.5	15.275	14.975	18.275	13.7775	9.6425	58.75	61.5	65.5	73	65.5
19	11.38	12.86	16.9	10.85	11.116	55.8	61.2	62.8	76	67.8
19.5	13.48	13.98	20.24	12.978	12.854	59.8	61.4	67	75.6	74
20	14.44	16.86	22.36	12.748	11.928	64.2	76.8	76	75.4	71.8
20.5	11.24	13.32	18.98	9.54	9.298	55.4	61.2	70.4	65.8	65.6
21	13.24	15.64	20.3	9.406	9.518	57.8	61.2	70.2	74.4	68.6
21.5	9.34	13.76	20.28	7.84	8.266	54.8	65.6	66.8	74.4	67.6
22	6.825	9.95	18.12	5.342323	5.625098	56.25	59	63.5	69.33333	66
22.5	14.2	14.6	25.45	12.39747	12.44473	66	71.5	71.25	72.5	72.25

DI, DP and RQI Data for Rigid Pavements (Continued)

CS-06111

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0		16.76	28.98		14.938	56.8	60.4	62.2	67.4	60.2
0.5		16.24	27.74		13.876	47.6	54.66667	53.2	59.4	54.4
1		17.28	34.28		14.83	62	67.4	67.8	70.6	64
1.5		18.6	35.94		14.71	60.6	61.2	64.6	67.8	64.8
2		14.4	21.74		11.688	60.6	61.8	58.6	68	62.8
2.5		5.08	9.8		3.976	39.2	36.2	36.6	39	43.2
3		4.22	9.04		3.226	42.6	41.8	42	44.2	48.4
3.5		6.34	11.1		4.812	50	47.2	49	50.2	57
4		7.78	13.24		5.66	52.2	51.2	55.4	54.8	59.2
4.5		6.3	14.98		4.696	49.25	49.5	56.25	54.5	61
5		7.98	23.02		6.42	55.8	61.6	67	64.5	66.75
5.5		8.34	14.54		5.34	49.2	46.8	50.6	51	57.6
6		8.12	12.6		5.082	45.8	45	44.6	45.6	50.8
6.5		7.36	11.98		4.866	48.2	48.2	48.8	51.2	53
7		6.76	13.74		5.242	46.4	46	48.6	51.4	51.8
7.5	N.A.	15.5	23.64	N.A.	9.702	56.4	58.6	59.33333	65.6	67.2
8		8.18	16.34		5.88	52	53.4	52.8	55.8	57.8
8.5		16.54	25.16		11.25	59	64.2	60.4	68	70
9		9.86	18.02		7.044	54.4	54.6	57.6	61.6	58.8
9.5		11.28	13.56		8.06	51.2	59.2	51.8	53.6	55.2
10		5.6	9.86		4	43.2	42.4	44	51.4	52.4
10.5		3.34	9.08		2.102	42	43	42.4	47	47.6
11		6.76	12.84		4.526	48.4	49	50.2	49	55.2
11.5		8.06	14.88		6.494	51.6	51.2	52.8	57.8	58
12		10.46	15.98		7.628	59.8	57	61.2	63.4	68.8
12.5		11.98	18.9		7.482	61.6	59.4	63.6	64.4	67.2
13		14.12	24.24		8.672	49.4	46.4	49.4	50.8	56
13.5		14.44	22.94		8.758	55.4	57.4	53.4	56.4	60.8
14		10.52	18.96		7.532	51.6	47.6	49.2	53.6	55.8
14.5		15	24.96		7.814	47	44.6	53.8	53.4	57.4

CS-06111

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
15		10.38	17.8		8.07	52	56	55.4	58.6	62.6
15.5		9.62	17.26		6.24	48.4	53.8	51.8	57.6	56.6
16		14.24	21.1		8.842	53.2	56.8	52.2	53.4	65.2
16.5		13.48	18.04		8.064	46.2	47.4	49.4	57	60.4

DI, DP and RQI Data for Rigid Pavements (Continued)

CS-11017

M.P.	DI			DP		RQI				
	93e	95e	97e	93e	95e	92e	93e	94e	95e	96e
1	25.06	24.58	0.66	24.302	4.8604	75.8	80.8	80.6	81.8	40
1.5	15.8	17.38	0.16	15.318	3.0636	69.4	73	75.6	76.2	34.2
2	12.88	14.06	1.8	11.128	2.2256	68	70.4	70.2	70.3	35.4
2.5	18.62	26.92	0.1	18.442	3.6884	76.6	80.2	81.8	77	39.2
3	13.36	20.64	0.84	12.24	2.448	66.8	69.8	73.4	73.8	33.6
3.5	25.24	33.24	1.5	24.362	4.8724	73	82.2	79.6	75.8	37.8
4	19.34	23.92	0.36	18.416	3.6832	75	77.8	82	78.8	40.4
4.5	24.6	27.52	1.14	23.886	4.7772	76.2	76.8	77.8	78.6	32.6
5	24.24	34.14	5.18	23.592	4.7184	87.2	91	91.4	90.4	29.8

CS-18024e

M.P.	DI			DP		RQI				
	93e	95e	97e	93e	95e	92e	93e	94e	95e	96e
2	12.36	32.28	35.37	8.674	27.314	56	56	58.8	61.4	64.8
2.5	8.44	18.68	15.692	1.96	10.192	56.4	56.6	56.4	59.4	62.4
3	7.2	33.4	24.114	0.6	21.22	48.6	46.4	48.2	48.2	52.2
3.5	4.82	30.8	14.896	0	18.372	52.2	53	52.2	54.2	58.8
4	7.46	45.08	18.386	0.864	32.392	49.2	49.4	48.6	51.8	56.4
4.5	9.46	56.58	22.53	0.902	44.56	50.4	53	53.8	55	57.6
5	11.68	53.22	27.028	1.576	35.916	54.8	54	60	58	62.4
5.5	15.38	53.62	28.51	4.748	42.94	53.6	54	55.8	60.6	64.8
6	11.9	33.92	24.64	0	18.156	53	52.4	53.2	55.2	57.8
6.5	12.16	39.14	26.868	1.75	25.618	56.2	58	63.8	63	72.4

DI, DP and RQI Data for Rigid Pavements

CS-12034

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0	32.46	38.32	36.9	26.686	30.61	74.6	73	76.8	75.5	80.6
0.5	37	42.88	39.88	28.802	32.444	66.8	68.4	69.6	71.6	76.2
1	35.76	44.44	37.2	27.174	33.3	70.4	71	72	73.6	80
1.5	24.16	29.46	28.54	17.698	20.136	65.6	66.6	67.2	70.2	72.2
2	20.4	27.6	25.6	17.292	21.566	57.2	57.4	57.4	60.8	62.2
2.5	33.26	45.98	41.9	28.876	38.716	69.4	70.4	76.4	74.6	73.2
3	43.38	50.02	45.88	34.792	40.956	71.6	73.2	73.8	74.4	74.6
3.5	43.64	52.98	52.72	39.102	46.366	70.4	74.8	77.4	72.8	72.4
4	33.94	40.3	40.94	31.82	35.414	71.2	73	74	78.2	73.4
4.5	35.16	40.94	38.86	30.67	33.26	70.6	73	76.8	78	73.6
5	40.66	50.56	46.34	35.478	43.044	74.8	77.4	79.8	77.2	76.6
5.5	32.52	40.6	39.66	27.798	35.09	67.8	70	71.8	72.4	72.6
6	34.18	42.84	45.84	31.846	38.778	75.4	74.6	76	76.6	79.8
6.5	27.375	32.57	33.075	24.03	27.87	64.75	67.5	73.5	71	70.5
7	30.34	40.38	37.8	26.94	34.1	69.4	70.8	71.4	73.2	74.8
7.5	29	39.9	38.74	25.526	34.58	65	67.8	71.4	71.8	70.2
8	35.68	41.28	41.72	31.706	35.288	69.4	74.6	75.6	75.8	71.4
8.5	30.88	43.32	39.1	25.238	35.298	63	67	69.4	71.2	68.4

DI, DP and RQI Data for Rigid Pavements (Continued)

CS-18024w

M.P.	DI			DP		RQI				
	93w	95w	97w	93w	95w	92w	93w	94w	95w	96w
2	14.1	25.62	37.62	6.564	17.976	59.8	58.8	59.2	65.6	69.4
2.5	10.52	28.66	40.72	7.466	25.212	48.2	46.6	53.4	54.8	65.8
3	2.04	8.48	19.14	0.392	4.75	51.6	52.8	53.8	55.2	57.6
3.5	1.1	10.8	20.66	0	7.038	51.4	52.2	51.8	55.8	58.6
4	8.04	16.38	30.1	1.962	9.312	47	48.4	50.4	56.6	56.8
4.5	12.66	16.14	26.34	0.4	8.626	48.2	49.4	49	51.2	55.4
5		23.3	29.82	2.84	12.422	50.8	55	54.4	56.2	63.4
5.5		31.14	38.3	8.2	16.194	52.6	55	54.8	59.2	62.4
6	9.12	19.2	29.36	0.586	8.16	52.2	52.4	52.8	57.4	62.4
6.5	4.95	17.75	27.575	0.738	6.215	48.75	55.4	48.5	53.75	58
7	10.94	24.88	29.72	4.708	18.108	54.2	55	54.6	58	62.4

CS-23063

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0	0.16	0.38	0.64	0.15	0		39.33333	39.66667	47.33333	50.25
0.5	0	0	0.48	0	0		32.6	33	38.4	41.4
1	0	0	0.48	0	0		36.8	37.6	41	43.8
1.5	0.2	0.4	2.02	0	0		39.4	41	43.6	48.4
2	0.2	0.2	4.1	0	0	N.A.	35.8	38.2	42	46.6
2.5	0.1	0	4.88	0	0		30.2	32.4	37.2	40
3	0	0.5	16.68	0	0		37	34.5	38.75	41
3.5	0.64	1.6	23.6	0.586	0.304		37.4	36.8	39.4	45
4	0.1	0.6	20.08	0	0		37.2	38.2	41	42.75
4.5	0	0.1	9.36	0	0		38.25	40.25	43.66667	44.2
5	0.1	0.2	5.14	0	0		37	39.75	42	43.66667

DI, DP and RQI Data for Rigid Pavements (Continued)

CS-21022e

M.P.	DI			DP		RQI				
	93e	95e	97e	93e	95e	92e	93e	94e	95e	96e
6.5	4.98	6.66	11.6	4.178	5.43	66.4	67	69.2	69.6	73.2
7	6.64	4.58	9.28	4.43	2.24	57.2	55.8	59.8	57.8	61.8
7.5	6.28	5.88	10.04	5.816	5.356	62.8	55	59.6	62	56.4
8	4.88	4.575	9.275	5.655	3.9525	75.4	67.2	77.2	75.4	70.5

CS-21025w

M.P.	DI			DP		RQI				
	93w	95w	97w	93w	95w	92w	93w	94w	95w	96w
0	12.625	19.55	17.25	4.712	11.7825	72.4	71.25	75.6	73.25	58.4
0.5	8.775	19.86	20.225	0.8175	9.172	64	66.2	64.8	64.8	64.4
1	8.6	20.72	19.02	1.382	9.65	61.2	59.8	60.8	60.8	61
1.5	3.8	11.88	12.14	0	2.93	53	52.8	54	54	57
2	4.5	12	12.12	0.688	1.914	49.8	52	51.4	51.4	52
2.5	5.56	12.74	13.72	0.586	3.284	50.6	54	54	54	53.8
3	7.625	10.35	13.44	1.78	4.7225	56.6	55	59.2	59.2	58
3.5	4.42	7.76	8.52	0.686	2.814	53.4	53.8	53.2	53.2	57
4	9.06	13.08	13.2	1.296	3.886	51.8	51.6	51.6	51.6	52
4.5	10.66	16.48	17.86	2.516	8.592	52.6	52.4	51.4	51.4	53.4
5	11.1	14.46	16.28	3.858	7.248	57.6	58.6	58.4	58.4	58.6
5.5	9.3	15.64	19.1	2.6	9.178	68.4	67.6	70.6	70.6	70

DI, DP and RQI Data for Rigid Pavements (Continued)

CS-21025e

M.P.	DI			DP		RQI				
	93e	95e	97e	93e	95e	92e	93e	94e	95e	96e
0	11.42	11.44	16.88	4.806	3.138	66	65.75	63.7	62	60.5
0.5	13.2	14.82	16.875	3.665	1.498	60.75	61.25	65.8	63.25	62
1	11.4	13.94	17.72	4.338	2.584	51.2	52.6	52.2	53.4	54.6
1.5	13.64	19.2	21.22	4.848	4.056	53.2	54.8	54.6	56	55.4
2	9.4	11.26	23.66	3.1	0.88	48.2	50.4	50.8	50.6	53.2
2.5	11.08	15.02	20.52	4.02	3.228	52.2	54	54	54.4	57.4
3	10.15	12.27	16.6	3.85	1.462	59.25	60.25	62.25	59.7	59.7
3.5	11.58	14.4	20.08	4.03	3.622	57	58.2	57.8	57.6	55.8
4	15.16	15.94	21.64	6.996	3.642	52.4	57.6	56	55	55.8
4.5	7.92	8.24	12.38	3.764	1.972	55.2	56.6	59.2	58.8	58.6
5	10.54	9.92	13.64	5.284	3.512	61.2	61.4	62.6	60.8	63.2
5.5	7.34	8.2	10.3	4.202	3.416	58	58.6	60.4	59.8	60

CS-63031n

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0	11.14	15.24	22.06	9.704	12.262	72	72	71.8	68.75	72.33333
0.5	11.2	17.76	20.74	10.736	17.01	67.6	66.2	68	66.4	69.6
1	10.78	14.44	18.9	9.236	13.18	66.2	67	65.8	66.8	65
1.5	15.84	15.22	17.12	12.998	13.58	66.4	61.4	62.6	60.25	67.25

DI, DP and RQI Data for Rigid Pavements (Continued)

CS-23061

M.P.	DI			DP		RQI				
	93s	95s	97s	93s	95s	92s	93s	94s	95s	96s
0	12.16667	14.93333	17.93333	9.348288	3.931111		71.2	72.4	75.2	74.2
0.5	8.95	14.5	20.92	5.287186	2.974		60.4	64.8	65	65
1	10.4	17.36	25.56	7.956	5.37		64.6	67.4	66.4	69.8
1.5	18.6	21.94	31.42	8.087025	8.974		61	64.8	64	64
2	8.92	16.6	26.6	3.94	3.382		58	57.8	59.2	61.2
2.5	7.04	14.88	24.38	3.648	3.272		54.8	55.4	56	57.2
3	10.9	14.5	20.65	3.499758	1.636596		65.75	66.75	65	63.33333
3.5	10.28	14.86	20.64	3.338802	2.902		61.4	64.2	65.2	62.8
4	13.2	17.2	17.26	8.986378	8.014		64.6	62.6	66.6	64.4
4.5	14.52	21	19.76	9.412	10.946		61.2	64.2	63.6	61.4
5	24.45	19.8	23.54	18.16369	10.01297		61	59.66667	65	67.5
5.5	33.6	22.55	27.175	29.73648	14.23437	N.A.	64.6	67.2	64.5	69.6
6	26.84	20.4	19.72	24.166	14.36		65.4	68.4	69.6	70.8
6.5	26.08	20.48	21.86	22.414	13.776		69.4	76.2	76	76.2
7	26.08	21.78	26.46	22.222	13.476		64	68.2	67.4	67.6
7.5	31.44	21.96	23.04	29.84	17.73		68.4	73	71	71.8
8	31.14	25.62	22.76	30.22	16.412		71.4	75	75.2	75.8
8.5	42	21.48	22.4	39.922	14.504		63	64.2	65	65
9	46.14	36.72	33.06	36.79376	16.412		64.2	65	68.5	67.6
9.5	15.24	13.26	14.76	10.67336	6.772		55.4	58.4	61	61.6
10	24.84	18.42	21.6	20.93923	11.634		67.6	70	70	69.4
10.5	25.78	21.06	28.16	20.124	14.132		73.2	75.8	74.8	76
11	27.9	23.6	30.2	25.076	19.812		67.2	69.6	69.2	69
11.5	26.02	23.84	32.32	19.35	16.398		64	66.6	65.4	66.2
12	13.225	9.76	20.2	13.14626	5.312895		50.75	52.75	52.25	54
12.5	13.025	15.05	20.2	8.382813	7.36206		56.25	56.75	57.5	59
13	22.03333	21.56	27.1	12.8	11.836		61.6	61.6	61.4	63

DI, DP and RQI Data for Rigid Pavements (Continued)

CS-25084

M.P.	DI			DP		RQI				
	93w	95w	97w	93w	95w	92w	93w	94w	95w	96w
0	20.8	18.175	25.35	18.05031	14.35984	61	63.75	63.25	66.75	68.2
0.5	21.76	24.92	30.98	17.74891	17.73	76	74.4	83	81.8	85
1	22.35	24.2	32.125	21.27964	15.295	75.5	70.25	74.5	70.66667	73
1.5	20.46667	17.86667	25.925	19.11571	13.65602	68	71	70.33333	71	74
2	26.3	22.075	29.65	25.8325	18.2829	65.75	74	71	72.33333	70.66667
2.5	31.6	27.65	34.7	29.66139	22.90355	69.75	79.25	74.25	72.25	74.75
3	35.14	31.72	39.325	29.01	23.738	61.4	67.6	67.2	68.6	69.2
3.5	31.1	30.325	42	24.97493	23.55692	56.5	61.5	63.25	65	70.33333
4	21.56	28.16	35.94	16.786	20.13	59.8	68.6	63.4		71.6
4.5	25.98	27.74	38.7	22.288	22.836	63.2	67	66.8		70.6
5	27.08	32	40.88	20.364	22.876	57.8	63.2	68.4		64.8
5.5	25.16	32.88	44.96	20.882	25.206	65.5	73.5	73.5		75
6	26.38	25.125	33.525	24.44737	20.64774	67.8	71.8	70		70
6.5	21.075	22.475	31.075	15.9719	18.20321	67.25	72	73.25	N.A.	75.25
7	14	16.24	27.16	8.818	11.432	66	65.6	68.6		72.2
7.5	8.08	9.1	20.46	4.788	6.924	64.4	66.2	67.6		69.6
8	5.44	6.5	13.36	2.89	5.098	58.8	61.6	62.2		64.8
8.5	7.94	8.78	19.3	6.413793	7.469219	64.25	66	69.75		73.66667
9	8.6	13.18	16.46	3.34	7.21	61.4	65	69.2		68.4
9.5	9.2	11.76	20.76	5.254	7.44	68.8	67	69.2		72.8
10	9.04	13.16	18.14	4.982	8.386	65.8	66	67.8		71.4
10.5	8.72	10.5	18.68	5.172	6.964	66.2	65.8	71.8		72
11	11.6	13.72	19.84	7.484	9.702	65.4	66.6	68.8		71.6

DI, DP and RQI Data for Rigid Pavements (Continued)

CS-25085

M.P.	DI			DP		RQI				
	93e	95e	97e	93e	95e	92e	93e	94e	95e	96e
0	12.83333	13.425	16.72	11.91343	10.16677	57.5	59.5	64.25	60	66.2
0.5	16.18	14.78	16.62	13.2972	12.694	55.4	58	61	62.8	65.8
1	12.325	15.42	12.36	11.1101	12.3045	55.6	59.6	61	61	64.2
1.5	10.98	9.15	14.24	9.78528	9.540081	53.75	58.25	63.25	63	62.8
2	7.825	10.34	12.36667	7.668704	9.547856	58	61.5	59.75	59.66667	67
2.5	12.92	12.05	13.85	11.164	11.0275	54.8	57.4	53.8	55.2	57.6

CS-44043

M.P.	DI			DP		RQI				
	93e	95e	97e	93e	95e	92e	93e	94e	95e	96e
0	24.84	26.12	23.84	20.174	18.34	75.6	77.2	79.2	79	81.4
0.5	26.74	32.98	27.8	21.008	21.522	70.8	83.4	78.2	76.2	76.8
1	29.84	29.18	32.26	19.26	21.214	67.6	70.8	72.6	72.2	75.8
1.5	31.78	35.28	34.24	18.762	17.172	67.6	74	72.8	71	75.8
2	28.68	33.08	33.26	19.464	24.084	72.6	76.8	79.4	74.2	80
2.5	20.4	26.92	23.58	13.874	18.632	69.6	72.4	78.2	71.2	72.8
3	13.02	19.66	19.66	8.072	13.734	67.4	70.6	74.8	71.6	74.4
3.5	13.08	17.02	18.1	7.638	11.208	66	70	71.2	68.6	71
4	9.1	15.58	17.84	5.188	11.458	62.2	65.6	65.4	63.4	69.8
4.5	12.26	17.6	18.74	7.31	13.192	65.8	69.6	70.6	70.2	74
5	12.28	19.02	17.44	8.182	14.882	61	63	63.2	64.6	67.4
5.5	14.625	18.25	18.8	6.86529	10.31699	63.5	65.75	65.75	68.5	74.33333
6	15.12	18.64	17.9	6.494	9.972	66.4	68.4	71.2	65.6	67.8
6.5	11.6	11.26	13.3	5.678	3.23	56.4	58.2	57.6	59.2	60.6

DI, DP and RQI Data for Rigid Pavements (Continued)

CS-44044

M.P.	DI			DP		RQI				
	93e	95e	97e	93e	95e	92e	93e	94e	95e	96e
0	2.125	1.42	3.916667	1.512292	0.79	41.33333	44	54	49.75	50.33333
0.5	0.15	1.4	5.6	0.148305	1.102112	39	40.6	39	45.75	44.33333
1	0.88	1.56	5.75	0.188	1.18	34.25	39	42.6	47.4	45.4
1.5	4.66	5.9	6.5	0.376	0.602	36.4	39.4	40.6	46.2	44.6
2	0.2	1.14	5.42	0.21	0.946	35	33.6	35.2	43.8	42
2.5	1.2	2.25	10.25	1	1.734707	39.8	40.4	40.8	49	51.6
3	0.76	1	5.92	0.380909	1	37.75	38.25	40.5	46	43.25
3.5	1.6	4.68	11.86	0.898	3.782	37.8	40.8	44.4	52	55.4
4	0.7	1.84	5.02	0.196	0.84	42.4	44	44.2	53.8	53.4
4.5	1.18	2.02	6.02	0.188	1.014	38.8	41.6	42.8	47.8	49.4
5	0.2	1.2	9.52	0	0.79	38.6	38	41.2	45.4	45
5.5	1.64	5.14	20.12	0.84	3.856	45.4	48.2	48.2	55.2	58
6	1.48	1.72	18.5	0.588	1.236	45.6	50.4	51.6	51.8	56.2
6.5	4.82	2.76	15.7	0.616	0.772	50.2	51.2	53.4	59.6	59.8
7	1.16	0.4	1.2	0.398	0	49.8	51.2	52.4	53.4	57
7.5	0.5	0.2	2.84	0	0	45.2	46.2	47.6	50.2	48.4
8	0.7	0.1	2.84	0	0	45.8	49	48.2	51.2	47.8
8.5	0.66	0.625	1.575	0.4	0.38	50.2	51.4	51.4	52.2	52.4
9	0.55	0.54	3.46	0	0	47.75	49	48.25	52.25	51.25
9.5	2	1.16	5.7	0	0.196	45	46	46.8	49	48.6
10	2.12	0.425	2.44	0	0.235	54.4	54	55.8	57.4	56.4
10.5	0.725	0.82	6.42	0.235	0.21	51.5	52.75	53.25	56.25	54.75
11	0.66	0.775	3.3	0.398	0.38	50.8	52.6	53.2	57.6	55
11.5	0	0.1	0.2	0	0	56.25	49.33333	59	51.66667	51.5
12	0.3	0.2	1.38	0	0	51.2	51.4	52.2	54.6	55.2
12.5	1.48	1.24	10.42	1.398	0.15	53.2	52.6	54.4	55.8	58.4
13	0.3	0.92	9.26	0.21	0.3	47.8	48.2	48.6	54.2	53
13.5	1.36	1.34	9.76	0.578	0	46.6	49	50.4	52.8	57.8
14	1.24	2.6	6.98	0.804	1.204	42.8	46.4	46.2	53.8	52.4
14.5	1.26	0.2	1.8	0.962	0	45	48.8	48.2	49.8	50.8
15	1.32	1.9	8.58	0.68	0.5	47.4	48.6	48.4	54	54

CS-44044

M.P.	DI			DP		RQI				
	93e	95e	97e	93e	95e	92e	93e	94e	95e	96e
15.5	0.3	0.1	1	0.196	0	47	49.2	48.8	53.8	52.2
16	0	0	2.225	0	0	45.4	47.2	48.2	52	51.8
16.5	0.575	1	7.3	0.2625	0.406	47.25	48.5	50	52	51
17	0.78	1.75	7.366667	0.594	0.788	44	45.2	46.4	51.6	53.8

DI, DP and RQI Data for Rigid Pavements (Continued)

CS-47065

M.P.	DI			DP		RQI				
	93e	95e	97e	93e	95e	92e	93e	94e	95e	96e
0	0	0.32	1.04	0	0		25.2	32.4	31.8	32.6
0.5	0	0.48	1.3	0	0.15		26.6	27.6	35	36.4
1	0	0.75	0.075	0	0		22.25	24	34.5	33
1.5	0	1.76	1.2	0	0		26.4	27	31	33.4
2	0	0.1	0.56	0	0		27.4	29	33.4	36.6
2.5	0	0.76	0.7	0	0.35	N.A.	24.2	29.2	36.4	34.4
3	0	3.46	2.1	0	1.68		23.8	26	33	34.2
3.5	0	3.02	0.98	0	0.8		27.8	28.6	34.4	35.4
4	0	2.16	0.28	0	1.28		21.4	23.6	33	32.4
4.5	0	0.375	0.5	0	0.24		25.5	25.5	30	37
5	0	0.78	0.6	0	0		29.2	29.4	35.2	44.75

DI, DP and RQI Data for Rigid Pavements (Continued)

CS-50112

M.P.	DI			DP		RQI				
	93e	95e	97e	93e	95e	92e	93e	94e	95e	96e
0	13.72	30.62	5.36	9.22	18.2	77.2	78	77.6	79.2	
0.5	16.6	32.72	4.96	13.95	21.45	78.4	76.8	79	79.2	
1	22.16	34	6.06	15.65	18.52	78.4	79.8	82	80.8	
1.5	25.04	38.54	5.72	17.22	25.31	77.6	83	84.8	82.8	
2	28.12	39.84	4.7	14.93	20.59	76.6	78.6	82.2	83.2	
2.5	22.76	37.78	6.18	15.51	23.61	79	84.2	86	86.6	N.A.
3	18.58	29.96	5.64	15.49	23.86	74.6	78	78.4	79.2	
3.5	20.375	30.35	3.32	12.94	19.13	73.5	79	80.25	76.5	
4	19.74	28.94	5.04	13.43	21.47	78.2	79.6	79.6	78	
4.5	17.74	26.28	5.36	11.6	18.06	71.4	74.2	71.8	73.2	
5	22.72	26.34	3.74	10.77	19.34	73.8	75.4	76	72.2	
5.5	33.46	56.7	3.66	17.97	38.44	80.4	80	81	83	

DI, DP and RQI Data for Rigid Pavements (Continued)

CS-58152

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0	0.96	2.26	8.7	0.15	0.15	43.4	44	45	48.6	46.4
0.5	0.233333	3.566667	9.55	0.079365	0.943637	47.66667	52.66667	54	46	
1	0.333333	3.6	8.475	0	0.276174	41.25	42.75	43.5	46	51
1.5	0.3	1.7	11.02	0	0	24	27.2	27.8	31.8	34.4
2	0.4	1.3	6.74	0	0	30	31.4	30.6	34.4	35
2.5	0.56	2.36	9.76	0.15	0	29.8	30	33.4	36.2	38.4
3	0.225	0.625	5	0	0.15	40.75	40.25	40	41	41
3.5	0	0.2	1.26	0	0	23.6	29.4	24	29.2	27.2
4	0	0.64	2.14	0	0.15	33.4	35.6	34.6	36	35.2
4.5	0.16	0.3	6.46	0.15	0	30.2	30.4	31.8	33	34.2

CS-39022

M.P.	DI			DP		RQI				
	93w	95w	97w	93w	95w	92w	93w	94w	95w	96w
4.5	0.64	1.9	3.22	0.196	0	44.8	48	50.6	50.6	54.2
5	0.1	1.3	2.38	0	0	46.4	51.4	50.8	50.2	53.6
5.5	0.54	2.02	5.42	0.338	0.21	49.4	49.6	55.2	49.6	54.8
6	0.04	0.9	1.64	0	0	50.8	50.6	52	51	53.2
6.5	0.3	1.7	4.24	0	0	48.2	52.2	52	51.6	53.4
7	0.74	4.38	7.56	0.526	0.376	53.2	54.6	54.6	59.4	59.6
7.5	6.02	14.2	26.82	1.624	0.572	57	62	65.8	64.4	72.4
8	2.16	11.7	17.16	0.772	2.634	53.2	56.4	59	61	63
8.5	6.58	16.92	42.16	2.508	3.584	56.6	55.6	59.2	60.4	65
9	4.84	10.28	19.76	0.938	0.892	49	53.2	57	61.8	63.2
9.5	7.78	15.36	30.42	3.396	1.82	45.6	52.6	58.4	61.6	67.4
10	4.48	9.12	21.52	1.682	1.358	52	56	59.4	62.6	64.2
10.5	14.44	18.72	37.74	2.474	2.926	51	59.2	66.6	66.4	74.4
11	1.58	8.5	14.66	0.36	1.592	43.75	50.75	48	48.5	52.5

DI, DP and RQI Data for Rigid Pavements (Continued)

CS-59012

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0	4.32		10.9	3.42			48.8	50.8	51.4	54.2
0.5	0.92		4.82	0.6			41	43.2	43.4	46.8
1	8.76		23.54	3.05			48	50	51	53.2
1.5	19.56		44.86	10.34			49	55.2	56	56
2	21.42		41.6	6.66			53.4	58.2	58	60.6
2.5	17.92		33.28	6.78			60.4	64.8	64.2	70.2
3	14.5		28.42	5.8			53.6	51.2	53	57.2
3.5	16.22		32.32	5.33			56	56.6	59.2	62.4
4	6.7	N.A.	12.4	3.29	N.A.	N.A.	53.4	54.2	55.4	59.4
4.5	1.34		2.9	0.45			40.6	42	42	47
5	1.14		4.82	0.49			39.8	40.2	43.4	45.6
5.5	1.775		6.2	0.19			43.75	45.2	46.6	43
6	2.9		7.38	1			39.8	39.4	40.4	44.8
6.5	4.04		10.58	1.09			40	41.2	42.6	45.8
7	3		5.7	0.43			40	49.6	49	43.5
7.5	4.06		9.76	1.54			44.6	44.2	45.6	48.4
8	4.24		11.44	0.9			40.2	39.8	40.8	40.5
8.5	4.74		9.34	1.34			34.8	35.4	38.6	39.6
9	7.82		17.52	1.22			41.8	41.8	42.6	45.8

DI, DP and RQI Data for Rigid Pavements (Continued)

CS-70014n

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0	7.18	10.38	11.78	5.816	8.992	N.A.	64.6	59.6	62.6	65.2
0.5	9.56	11	14.4	7.826	9.758		59.2	59.6	61.6	65
1	7.2	7.36	12.08	6.126	6.144		56.6	56.8	58.8	59.2
1.5	9.56	14.82	14.26	8.788	13.156		57.4	57.2	58.4	63.2
2	9.96	14.62	16.98	9.232	12.442		60.6	59.4	60.6	67.8
2.5	5.92	8.18	10.86	5.278	6.766		60.2	63	61.8	65
3	3.8	4.26	4.8	3.486	4.102		57.6	55	59.2	61
3.5	2.9	3.4	5.4	2.792	3.134		60.4	60	61.6	62.8
4	6.66	6.9	9.58	5.062	5.608		60.6	59.8	62.2	66.2
4.5	7.34	8.16	9.44	5.91	6.548		68.4	65.4	67	69.8
5	4.9	4.98	7.24	4.516	4.238		65.2	68.6	68	57

CS-70023e

M.P.	DI			DP		RQI				
	93e	95e	97e	93e	95e	92e	93e	94e	95e	96e
0	27.74	30	31.9	12.562	15.172	N.A.	77.4	80.8	79.25	83.5
0.5	11.65	12.05	10.66	7.075	9.3725		73.5	71.6	69.75	79.2
1	13.8	9.96	14.52	4.766	8.192		75.4	69.2	73.4	72.6
1.5	13.38	14.44	14.46	9.058	8.628		74.8	72.4	72.8	72.8
2	17.62	17.34	19.1	12.464	12.868		74.25	76.2	75.5	80.2
2.5	11.78	9.96	12.54	3.168	4.348		69.2	66.6	69.6	68.6
3	8.7	10.7	13.12	4.624	5.982		74	72.8	71.25	71
3.5	9.12	12.3	14.08	6.492	8.46		71.4	69.4	71.6	72.3
4	10.8	12.38	12.7	6.612	7.928		71	73	71.5	74
4.5	8.14	10.14	12.08	4.644	7.342		58.2	61	59.6	62
5	15.62	9.05	10.32	7.175	6.558		61.4	62.4	64.8	64.4

DI, DP and RQI Data for Rigid Pavements (Continued)

CS-76024e

M.P.	DI			DP		RQI				
	93e	95e	97e	93e	95e	92e	93e	94e	95e	96e
0	1.82	2.66	7.6	0.196	0.676	32.6	34.2	37	43.6	46
0.5	0	0.38	3.38	0	0.188	29.4	28.2	30.4	36.8	36.2
1	0	3.08	5.32	0	0	32	34	36.75	47	48
1.5	0	2.52	7.06	0	1.922	32	31.2	32.8	37.6	44.2
2	0.02	2.92	4.62	0	0	37.5	37.25	39	40	45.33333
2.5	0.18	1.38	13.18	0.188	0.496	35.2	33.4	34.2	37	41.6
3	0.2	1.2	6.46	0.196	0.746	36.8	35	36.6	40.2	42.4

CS-21022w

M.P.	DI			DP		RQI				
	93w	95w	97w	93w	95w	92w	93w	94w	95w	96w
0	5.6	18.08	24.2	1.4475	9.668	55.2	57.4	64.6	56.3	64
0.5	8.42	14.9	17.96	1.128	5.912	45	44.75	47.75	51.75	55.5
1	11.06	16.52	19.78	1.152	6.866	46.2	46.8	53	55.4	67.6
1.5	8.14	14	17.76	0.188	5.146	50.8	53.4	56.2	57.3	63.75
2	15.775	3.88	7.06	9.53	0.764	62.2	60.2	18	22.8	29.6
2.5	11.62	3.66	5.24	6.498	1.128	58.8	60.8	11.6	16.4	21.2
3	18.72	3.28	7.16	10.098	0.388	68.75	68	20.75	22.5	27.5
3.5	13.825	5.45	5.3	10.3125	2.9125	69.6	69.8	29.2	27	31.75
4	14.525	7.06	9.14	5.4625	3.03	56.4	59.4	29.8	32.2	34.2
4.5	10.35	3.32	5.4	4.9925	0	66.6	68	28.6	29	33
5	12.74	2.2	5.08	10.576	0	74.8	76.6	23.8	25.2	27
5.5	21.84	1.78	3.76	12.034	0	81.8	82.6	20	26	29.4
6	10.06	8.64	8.36	7.736	5.658	71.2	69.4	40.4	40.8	45.4
6.5	7.54	11.12	12.12	3.95	7.41	62	63.2	66.4	64.2	63.6
7	5.14	8.34	8.1	3.418	6.23	58	55.6	60	58.8	61.2
7.5	5.26	11.36	12.84	3.184	9.67	52.2	52	53.8	55.6	53.2
8	8.35	9.9	14.875	6.3775	8.6925	74.5	66.75	70	62.25	71.75

DI, DP and RQI Data for Rigid Pavements (Continued)

CS-80023

M.P.	DI			DP		RQI				
	93e	95e	97e	93e	95e	92e	93e	94e	95e	96e
4	18.34	33.28	34.4	11.22	25.03	73	73.6	75.8	77.4	81
4.5	17.98	29.94	34.46	10.57	19.93	69.2	72	74	75.6	77.4
5	18.26	31.34	32.72	11.28	22.59	68	72.4	75.2	76.2	78
5.5	18.58	23.86	28.52	11.48	16.36	62.6	65.2	68	69.6	71.2
6	21.02	27.32	36.82	13.33	19.04	71.6	76.6	79.8	78.4	81.8
6.5	18.22	23.14	31.26	11.12	14.46	67.6	71.2	72.6	73.4	76.8
7	16.74	24.46	33.42	10.71	17.27	69.8	75.4	76	76.5	80.4
7.5	16.82	21.62	33.16	8.94	13.82	66.8	71.8	74	73.6	78.2
8	17.2	20.14	31.88	10.1	12.15	63.6	68.2	69.2	71.2	73.6
8.5	15.4	20.3	33.88	7.4	8.69	70.8	75.6	77.4	77.4	79.4
9	17.74	19.66	32.42	9.72	6.56	72.8	75.8	77.6	78.6	81.2
9.5	19.04	20.86	34.74	11.93	11.44	74	76.8	77.6	76.8	79
10	16.34	18	28.04	9.34	9.3	66.6	71.4	73.6	75	77.6
10.5	16.56	20.5	29.72	8.29	10.77	69	70.8	73	73	76.8
11	18.26	19.8	29.76	13.28	10.19	66.2	67.8	71.4	74.6	74.2
11.5	12.9	15.52	29.52	8.9	7.9	57.4	61.4	62.8	65.2	69
12	13.12	15.08	27.98	7.89	8.63	61.8	67.2	68.2	71	73.2
12.5	9.1	15.22	30.98	7.79	12.03	61.4	67.4	68.4	69.2	73.6
13	7.68	18.05	32.8	8.92	14.59	58.6	68.5	69.2	70.6	75.2

DI, DP and RQI Data for Rigid Pavements (Continued)

CS-80024

M.P.	DI			DP		RQI				
	93e	95e	97e	93e	95e	92e	93e	94e	95e	96e
5	15.875	10	28.025	8.54	1.658	60	64.75	67	68.5	69.75
5.5	0.1	1.6	11.6	0	0.304	49	52.2	49	52.6	57.8
6	0.16	0.2	7.54	0.15	0	46.6	49	47.4	49.8	52.2
6.5	0.4	0.48	17.92	0	0.188	48.8	54	55.8	51.8	55.6
7	0	0.5	20.72	0	0	50.8	52.8	57.8	54.4	59.6
7.5	1.2	1.98	32.88	0.92	0.384	47	49.6	57.6	51.2	55.2
8	0.68	1	20.4	0.68	0	48.6	49.8	50	52.8	57.2
8.5	0.58	0.2	11.6	0.49	0	49.8	50.8	47.6	52.8	55.6
9	4.82	4.6	20.36	2.3	0.588	51.6	52.8	52.2	57	61.2
9.5	0.74	0.6	10.04	0.34	0.196	51	51.8	53.4	56.8	58.8
10	0.9	1.38	8.86	0.81	0.196	49.4	50.2	48.75	53.2	56.2

CS-34043

M.P.	DI			DP		RQI				
	93e	95e	97e	93e	95e	92e	93e	94e	95e	96e
0	0.04	0.28	0.3	0	0	41.75	43.5	41.75	52	47.25
0.5	0	0.3	0.4	0	0	43.8	44	44.4	45.4	47.4
1	0.2	0.25	0.16	0	0	37.4	39	40.2	40.6	44
1.5	0.04	0.4	0.24	0	0	43.4	41.8	44.4	44.8	46
2	0	0.9	0.62	0	0	46	45.8	47.2	49.2	49.8
2.5	0	2.08	0.32	0	0.69	46.4	47.4	47.6	50.2	51
3	0.32	1.7	0.2	0.3	0.386	41.2	40.8	41.8	45	49
3.5	0.32	0.9	0.68	0.3	0	44.2	46	45.8	46.4	50.2
4	0	0.96	0.42	0	0.15	44.8	44.8	46.4	48.4	49.8
4.5	0	5.74	0.8	0	0.304	45.2	45.8	47.4	49	50.2
5	0	2.42	1.5	0	0.534	48.4	50.8	51.6	53.4	54
5.5	0	2.04	0.3	0	0.908	47.2	48.6	47.8	48.8	52.8
6	0	2.58	0.16	0	0.912	42.2	43.4	44	47.2	46.6
6.5	0.5	5.34	0	0	2.336	43.8	45.4	45.4	50.4	50

DI, DP and RQI Data for Rigid Pavements (Continued)

CS-81076

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0	33.18			26.92		83	88	88.6	85.8	89.4
0.5	16.04			15.46		77.6	80.6	78.8	78.2	77.4
1	17.13333			12.25		79.2	82	85	82.8	83.8
1.5	14.54			11.24		79.4	81.8	82.8	82	83.6
2	14.88			13.32		77.4	78.2	81.2	79.6	80.4
2.5	15.92			14.19		78.2	80	81.4	76.4	80.6
3	19.86	N.A.	N.A.	18.27	N.A.	74.8	80	79.4	77.4	79
3.5	19.14			18.03		73	80.4	77.4	80.6	81.6
4	16.06			15.81		72.2	77	77	77.2	74.2
4.5	24.5			22.83		85.2	85.2	83.2	85.8	81.6
5	28.2			23.05		92.2	89	85.6	90.2	91.2
5.5	21.64			19.62		76.8	83.2	79.6	82	80.4
6	26.22			22.65		73.4	79.4	80	79.6	80

CS-39014

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0		50.84	54.66		44.57	67.6	72.4	79.4	71	73.8
0.5		47.56	46.78		44.07	71.8	74	75.6	76.6	77.2
1		27.02	37.6		23.17	69.2	70.6	76.4	77.8	77.2
1.5	N.A.	15.94	20.62	N.A.	14.48	70.2	72.6	69.8	73.8	73
2		33.38	29.68		22.67	69.8	72.8	74.8	77.2	76
2.5		28.6	32.875		23.78	67.5	67.75	73.5	72.5	69.5
3		23.94	33.58		20.68	66.6	70.4	68.2	66.5	66.25
3.5		26.62	36.8		23.25	67	71.4	68.8	68	69.2

DI, DP and RQI Data for Rigid Pavements (Continued)

CS-82122

M.P.	DI			DP		RQI				
	93w	95w	97w	93w	95w	92w	93w	94w	95w	96w
2	7.86	10.38		6.68	8.95	51.4	53.2	57.4	58	54
2.5	7.36	7.96		4.3	5.72	47.6	55.8	57.2	53.6	59
3	4.3	10.56		2.69	7.98	51.6	54	65.8	58.4	66
3.5	16.64	31.68		8.38	29.45	68.4	62.2	75.8	60.2	77.6
4	17.2	22.8		14.27	20.54	58.8	65.6	60	64.2	68.2
4.5	11.36	18.68		9.43	12.46	56.2	61.2	63	65	64.2
5	15.94	22.36		12.33	15.7	55.4	63	52	62.4	52.4
5.5	10.38	12.98		6.52	7.18	49	46.8	49.2	49.6	47.2
6	11.24	15.72		6.28	8.51	43.6	43.8	45.6	44.4	49.4
6.5	8.74	11.24	N.A.	4.88	6.55	54.2	47.6	53	52.8	57.2
7	5.88	12.96		5.09	11.55	55.4	50.2	57.4	52.8	57.6
7.5	6.02	13.96		4.34	4.79	57.4	55	55	58.2	54.4
8	2.88	8.1		2.7	6.64	52.6	39.4	53.8	42.4	50.2
8.5	9.16	16.46		7.2	13.13	63.6	63.8	71.2	58.6	62.6
9	10.075	19.475		6.11	13.79	78	71.25	72.25	63.7	72.25
9.5	8.86	21.68		4.85	15.66	59.6	68.2	69.6	62.6	70.2
10	12.7	21.4		6.94	13.61	63	61.2	58.2	60.4	70.8
10.5	7.86	17.1		4.02	12.01	58.2	57.6	60	63	65.8
11	10.28	19.92		6.94	12.83	62.2	59	62.8	63.2	70.6
11.5	8.38	15.74		4.87	10.56	54.5	59.8	52.5	58.5	53

DI, DP and RQI Data for Composite Pavements (continued)

CS-06072n

M.P.	DI			DP		RQI				
	'93n	'95s	'97n	'93n	'95s	'92n	'93n	'94n	'95n	'96n
0	50.58333	34.425	1.24	35.49709	19.57238	88.5	98.75		42	47.75
0.5	13.48	0.62	5.76	7.512	0	44	48.8		33	39.4
1	13.78	40.8	31.18	6.5	25.258	46.2	47.4		44.8	47.2
1.5	19.35	55.5	30.94	12.12671	42.6925	52	58.75		50.66667	54.66667
2	25.58	58.3	40.4	20.106	46.796	47.6	46.2		51.6	41
2.5	16.78	49.84	32.16	8.692	33.726	42	44.8		53.4	45.6
3	13.58	36.88	26.56	7.222	21.496	42.2	44.2		47	51.4
3.5	7.94	41.72	25.52	1.14	22.474	34.8	39.6		36.8	40.2
4	9.475	24.275	15.66	2.727377	7.335	48	47.25	N.A.	51.25	58
4.5	12.2	38.92	25.18	6.512	15.7	55.6	56.6		59.2	63.2
5	7.22	25.94	18.4	2.154	12.306	46	48.8		49.2	53.6
5.5	2.12	17.32	6.82	0.188	6.706	33.4	35.6		42.6	43.4
6	5.26	17.94	11.24	2.528	6.772	40.4	42.6		45.2	48.6
6.5	21.3	34.08	35.38	14.65186	16.792	62.6	64.8		70	74
7	36.45	52.525	55.3	24.63269	32.405	77	84.66667		82.33333	82.66667
7.5	19.56	76	61.84	13.972	42.21	61	58.6		67.6	73.4
8	37.14	168.72	78.64	21.17	85.498	59.2	54		62.8	68.4
8.5	28.72	114.12	72.36	24.68	77.378	63.8	64.6		66.6	75.4
9	19.26	122.66	90.58	18.81593	63.412	61.8	62.8		67.8	78.8

DI, DP and RQI Data for Composite Pavements (continued)

CS-10031n

M.P.	DI			DP		RQI				
	'93n	'95n	'97s	'93n	'95n	'92n	'93n	'94s	'95n	'96s
0	69.66	70.58	88.84	44.328	47.674	45	50.6	48.2	54	53.6
0.5	65.62	67.28	96.14	42.36	41.972	48	50.8	50.2	54.4	56
1	94.74	70.46	83.42	60.176	48.33	58.4	60.4	62.6	61.8	67.8
1.5	88.1	67.22	170.14	54.344	45.254	52.6	56.4	55.4	54.8	58.8
2	81.9	64.7	94.06	48.982	46.084	50.4	57	55.8	62.2	59.2
2.5	51.04	37.7	85.7	24.056	21.172	55.8	53.4	57.2	58	64.6
3	54.12	46.7	71.08	31.412	31.058	55.2	54.4	58.6	61	60.8
3.5	53.04	44.56	58.78	36.08	33.036	52.6	56.8	58.8	59.2	60.8
4	28.48	31.24	108.6	11.878	14.282	47.4	47.4	50	51.4	55.4
4.5	45.04	39.16	89.6	19.37	19.008	56.6	62.8	62	65	66.2
5	74.72	56.96	79.36	52.69	41.2	68.6	67	67.4	70.4	71.4

DI, DP and RQI Data for Composite Pavements (continued)

CS-18011

M.P.	DI			DP		RQI				
	'92e	'94e	'96w	'94e	'96w	'92e	'93w	'94e	'95w	'96w
0		24.65	58.125	12.208	15.88	43.8	54	50.4	56.4	61
0.5		32.98	31.95	16.84543	21.635	47	49.25	54.25	54	58.75
1		28.22	49.06	17.79	30.664	42.2	45.2	58	50.4	60.4
1.5		23.4	63.14	13.414	37.402	46.2	50	59.6	58.6	63
2		25.06	38.4	17.572	17.552	46.6	48.6	52.8	52.6	55.6
2.5		28.38	38.8	21.11	22.028	47.8	46.8	53.8	48.6	52.4
3		21.06	25.8	13.974	14.006	46.2	46.4	47.2	51	56.8
3.5		36.84	39.12	29.878	26.568	50.8	54	61	58.8	64.4
4		46.32	28.86	39.73495	18.606	52	52.8	64.6	55.4	59.2
4.5		34.225	41.64	27.8275	32.106	57.5	59.75	58.5	66	68
5	N.A.	26.06	43.48	20.984	32.226	59.2	60.2	57.4	63.4	68.2
5.5		12.9	47.1	7.276	28.636	51	52.8	45.8	57	58.6
6		33.42	59.4	22.462	40.116	51.4	58.6	60.8	65.4	67.6
6.5		32.26	89.42	25.416	60.168	62.8	62.8	53.2	67.8	71.6
7		24.94	30.82	21.706	21.01	38	40.6	49.6	44	51.6
7.5		18.18	41.34	11.388	31.518	54.8	54.6	48.2	56.6	61.2
8		15.32	45.52	8.864224	35.092	52.4	55.8	59.2	58.8	62.6
8.5		24.96	45.92		19.804	61	59.4	72.6	67.6	69.6
9		33.04	23.9	21.66779	6.938	54.4	48	67	62	66.6
9.5		31.02	42.28	18.598	30.98	44	48.4	55.4	59.2	62.2
10		36.34	66.96	22.586	52.094	59.4	65	58	69	68.4
10.5		42.26	81.68	30.758	54.01	57.6	60	60.8	65.6	70.6
11		35.08	57.52	24.348	38.922	57.4	56.8	56	59.6	65
11.5		34.6	72.36	25.80532	55.462	54.4	60.2	63.4	64.8	72

DI, DP and RQI Data for Composite Pavements (continued)

CS-22012

M.P.	DI			DP			RQI				
	'92n	'94n	'96s	'92n	'94n	'96s	'92n	'93n	'94n	'95n	'96s
10.5	37.06	35.24	39.84	21.654	15.774	25.184	46.4	49.6	55.8	60.4	58
11	36.16	39.28	39.54	21.064	19.68	22.176	47	41.8	46.4	56	61.2
11.5	27.38	33.9	42.68	14.08008	14.63217	26.285	45.4	46.6	54.8	55.4	63.8
12	24.12	21.76	46.92			24.69	30.8	31.8	34.8	39.2	41.8
12.5	36.58	35.24	44.16	21.56135	16.832	26.25227	48.8	43.4	46.25	51	63.8
13	28.68	28.56	34.26	19.478	13.516	18.768	51.2	46	48.2	55.6	65.4
13.5	26.44	23.62	32.66	15.232	4.66	13.536	45.2	35.8	37	42.8	61.2
14	30.56	15.56	24.48	22.718	3.98	6.842	49.4	39.6	42.8	47	63.4
14.5	30.2	15.16	20.72		1.67372	5.36	33	36.8	36.6	41.4	55
15	23.7	19.9	43.475	16.62	9.995	30.74774	42.4	40.2	40.6	46.2	60.2
15.5	42.3	22.5	51.84	17.464	14.818	43.768	45.8	42.8	47.2	51	65

CS-76012n

M.P.	DI			DP			RQI				
	'92n	'94n	'96n	'92n	'94n	'96n	'92n	'93n	'94n	'95s	'96n
2.5	12.16	18.48	39.94	6.24	10.62	24.462	43.6	49.6	51.6	53.2	61.8
3	14.98	17.46	43.68	7.851346	10.9025	26.28	44.2	43.8	51	55.2	56.4
3.5	10.9	20.65	37.12	7.173898	10.82343	20.5	38	38	42.6	45.8	53.6
4	13.26	26.375	40.575	12.6569	12.53704	25.88	35.8	39.6	44.8	40.4	49.8
4.5	11.44	23.54	36.08	8.608405	13.92361	19.585	43.2	42.8	47.2	53	58.2
5	13.34	32.06	58.9	3.345	7.25	11.42	27.8	27.4	35.8	40.8	44.8
5.5	11.54	14.44	29.86	5.688057	8.832	18.888	46	38.4	48.4	57	62.4
6	7.6	12.65	39.95	3.863014	8.786364	26.44	34	31.2	36.8	47.4	52.2
6.5	9.3	16.8	47.14	7.62			39.5	48.25	43.5	36	41
7	15.22	16.82	29.92	6.604	9.518	14.6	48.6	50	51.8	47.4	63.4
7.5	14.94	16.76	28.64	5.882	8.528	11.366	48.2	48	66.2	47	69.8

DI, DP and RQI Data for Composite Pavements

CS-25131n

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0	7.58	14.88		3.412	10.64	49.4	51.2	60	57.6	62.6
0.5	7.4	14.96		4.652	11.378	45.4	50.4	56.6	59.8	58.4
1	8.76	18.32		0.96	5.802	38.2	40	44.6	46.2	54.4
1.5	7.32	18.36		0.398	5.47	36.2	40.8	41	46.6	57
2	15.875	32.3		4.280904	15.06756	48.25	57.5	58.25	58.5	
2.5	7.42	21.22		0	4.928	36.6	39.6	40.4	42	45.6
3	11.95	23.76		2.604839	6.623355	42.75	40.75	45.5	51	52.66667
3.5	4.16	16.32		0.388	6.92	30.4	30	32.4	40	42
4	5.78	16.32	N.A.	0	5.466	29	32.4	42.6	41.4	47.2
4.5	6.28	17.42		0	5.030081	38.6	48.8	43	52.8	59
5	6.34	21.2		0.73281	7.18698	33.8	37.4	40.4	46.2	47.4
5.5	5.22	20.98		0.768	7.268	38.2	42.8	44.8	53.4	54.6
6	4.28	16.5		0.388	6.326	30	35.6	36	41.2	47.6
6.5	3.62	16.78		0.2	6.69	31.4	35	37.8	42.6	43
7	3.42	15.04		0.492	7.27	30.2	33.4	33	41.8	49.2
7.5	3.74	14.48		0.188	5.352	31.8	33.6	36.4	40.6	42.2
8	3.68	12.26		0.188	4.456	33.8	36.8	39.4	47.8	52.6

DI, DP and RQI Data for Composite Pavements (continued)

CS-38083e

	DI			DP		RQI				
M.P.	'93e	'95e	'97e	'93e	'95e	'92e	'93e	'94e	'95e	'96e
3	21.14	57.92		12.868	34.736	82	89	90	85	87.2
3.5	35.7	51.92		19.684	32.492	66.6	70.6	80	77	78.6
4	44.28	58.16	N.A.	32.416	41.482	62.2	65.2	70.8	69	73.8
4.5	29.86	49.22		22.316	28.9	64.6	64.2	68.2	65.6	68
5	30.74	52.66		18.29	30.844	61.2	64.6	68	64	67.6
5.5	65.36	54.5		20.166	31.944	68	68.4	68.2	70.33333	73.6

DI, DP and RQI Data for Composite Pavements (continued)

CS-38101e

M.P.	DI			DP		RQI				
	'93e	'95e	'97e	'93e	'95e	'92e	'93e	'94e	'95e	'96e
0	20.44	29.7	36.78	10.28	15.02	40.2	41.6	45	50.2	54.2
0.5	24.34	37.04	44	10.93457	21.28902	43.8	46.6	48.6	56.4	58.4
1	20.54	36.525	24.26667	11.4225	17.26	44.75	40.25	49	54.5	51
1.5	22.14	35.34	34.92	7.448	13.618	37.8	40.2	45.6	50.2	58.4
2	18.22	23.96	25.52	4.488	5.14	41.2	44.2	46.6	50.2	51.6
2.5	13.06	23.7	21.84	3.24	5.68	38.4	37.8	44.4	48.8	49.4
3	11.56	17.58	21.02	3.044	3.816	38.8	37.6	44.4	46.8	50.8
3.5	12.46	18.08	23.82	3.948	4.373836	35	37.4	42.8	48	50.4
4	23.725	31.9	40.55	10.72907	16.47326	50.5	51	59.75	62.75	67
4.5	11.96	15.5	27.32	5.276	8.933967	36	41	43.4	42.6	45
5	19.2	29.04	36.04	9.522857	15.68508	50	51.4	56	56.6	57.4
5.5	11.04	19.92	25.5	3.888	7.98	38.4	37.8	42.2	43.4	44
6	10.46	20.62	25.58	4.388	7.994	40	42.2	46.2	49.4	54.4
6.5	12.4	18.02	29.92	6.481813	10.6855	40	42.6	43	48.2	53.4
7	23.62	35.82	38.8	15.06608	24.8772	64	65.4	67	71.6	70.2
7.5	15.74	26.96	34.44	4.956	11.572	36.8	38.8	42.8	47.8	50.2
8	17.08	29.88	35.7	5.675	15.14679	37	36.2	41	44.8	47

DI, DP and RQI Data for Composite Pavements (continued)

CS-38131n

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0	14.775	16.95	28.525	2.843269	2.959273	46.8	57	56.8	56.8	57.75
0.5	13.4	15.76	28.9	2.008	3.335	42.8	44.6	47.4	50.2	57.8
1	12.275	15.25	23.575	1.999521	4.303854	43.75	46.5	51.75	39.33333	46.66667
1.5	13.58	19.12	30.9	4.708	4.902	45.4	41.6	53.6	53.8	57
2	20.54	27.22	45.04	4.484	5.258	36.6	37	45.6	49.6	56.2
2.5	17.12	19.88	33.02	7.192	5.752	47.4	47	52.2	56.2	59.2
3	14.425	17.775	33.25	7.340556	6.123101	40.5	43.5	45.33333	55.8	52.75
3.5	17.42	18.48	37.02	8.146	6.54	38	43.4	46	47.2	50.4
4	17.58	22.62	42.5	8.68	7.144	42.8	39	45.2	47.6	55
4.5	16.16	18.8	29.96	6.71	8.872	49.4	46	54	55	58.6
5	22.475	20.375	34.25	12.89333	10.41957	55.8	52	58.8	59.2	63.6

CS-11011

M.P.	DI			DP		RQI				
	'93e	'95e	'97w	'93e	'95e	'92e	'93w	'94w	'95w	'96w
0	6.5	26.7	18.925	0.188	12.65	46.8	39	48.8	44	50
0.5	9.48	25.14	36.88	0.376	9.448	43.2	38.6	67.6	49.2	53.4
1	8.82	27.08	36.9	0.964	12.048	43	39.4	56.6	49	54.4
1.5	8.54	23.5	29.68	0.572	5.244	40.6	35.8	37.4	44.2	59.2
2	10.8	25.46	40.06	0.574	4.77	43.4	38.6	42.2	44.5	52.8
2.5	10.52	29.28	39.04	1.44	9.1	46.8	40.4	45.8	45.33333	50.8

DI, DP and RQI Data for Composite Pavements (continued)

CS-39024e

M.P.	DI			DP		RQI				
	'93e	'95e	'97e	'93e	'95e	'92e	'93e	'94e	'95e	'96e
1	15.86	17.26	37.74	6.048	4.594	29.2	33.4	36.2	43.4	40.8
1.5	20.1	14.26	34.56	9.742	1.344	24.4	28.4	32.8	43.5	39.4
2	19.06	16.74	43.36	10.118	4.672	38.4	43.2	49.6	54.8	48.6
2.5	20.72	18.5	38.34	12.026	7.19	35.4	42.2	48.2	53	47.8
3	21.78	20.06	34.9	11.594	7.316	36	41.2	43.6	49.8	46
3.5	20.48	15.7	35.02	11.002	5.172	37.4	45.2	47.8	50.6	49.2
4		9.6	33.3		7.02	59	53.4	50	52	51
4.5		1.82	9.966667		0	85.2	37.4	36.8	42.4	43.6
5		5.36	17.6		0	82	29.6	34	39.8	40.4
5.5	N.A.	5.2	17.88	N.A.	0	84.4	31.4	34.8	40.2	41.6
6		4.45	17.6		0	90.5	47	36	43.5	44.5
6.5		2.275			0	83	44.25	42.25	40	42
7		1.1	18.18		0	83.4	33.6	28.4	38.8	40

CS-81104e

M.P.	DI			DP		RQI				
	'93e	'95e	'97e	'93e	'95e	'92e	'93e	'94e	'95e	'96e
0	47.1	19.6	63.4	28.04	8.57	41.8	48.4	45.8	53.4	63.2
0.5	34.74	26.36	63.78	20.532	13.398	41.2	45	46.4	50.6	60
1	42.66	30.64	90.2	27.516	16.63	40.6	48.6	47	56.6	62.2
1.5	54.18	35.78	55.36	23.216	15.63	47	56.4	59.2	57.4	59
2	38.175	37.4	116.3	20.9075	14.81593	43	53.25	60.75	52.66667	65
2.5	42.16	35.6	193.76	25.278	12.96	46	52	62.4	62	72.6
3	48.35	37.85	67.96	33.785	15.79	52.75	54.25	64.75	63	68.5
3.5	50.1	33.5	77.86	24.442	9.566	47.6	56.6	64	65.8	68.6
4	34.82	28.2	60.9	19.646	11.56	44.8	54.4	57	63.2	64.4
4.5	35.52	28.98	66.14	19.2	10.698	48.2	55.4	53.8	59.4	70.6
5	35.16	27.48	59.76	23.95	8.19	42.6	52.8	60.2	61.2	63.8
5.5	42.2	30.06	55.48	24.758	10.214	43	47.2	54	60.2	64.4
6	38.92	31.32	60.14	23.964	11.852	39.2	39.8	49.4	52.2	54.4

DI, DP and RQI Data for Composite Pavements (continued)

CS-46011n

M.P.	DI			DP		RQI				
	'93n	'95n	'97s	'93n	'95n	'92n	'93n	'94s	'95n	'96n
0	35.94		58.95	25.136		54.4	60.8	65.2	65.4	71.2
0.5	68.575		115.55	29.30416		66.75	73.5	74.5	73	81.66667
1	29.9		42.28	20.522		68.8	70.4	75.4	74	82.6
1.5	25.74		53.04	15.276		63.6	64.6	72.8	69.8	71.2
2	27.62	N.A.	90.52	14.372	N.A.	58.2	61.4	64	65.6	71
2.5	54.5		88.42	25.578		57.8	58.6	55.2	61.6	71.6
3	49		91.44	19.156		58	63.8	58.2	69.4	68
3.5	65.26		76.06	40.226		61.2	67.2	63.2	69	67.8
4	82.9		64.86	50.602		65.2	71	57.6	73.4	73.6
4.5	61.84		60.12	32.326		62.2	68	64.8	69.8	68.4

CS-26011

M.P.	DI			DP		RQI				
	'92n	'94n	'96s	'92n	'96s	'92n	'93n	'94s	'95n	'96s
0	34.72	56	57.12	13.998	33.02013	59.4	62.4	62.4	66	72.2
0.5	37.04	61.8	70.04	20.094	38.226	63	61.8	64.6	67.8	81.8
1	54.7	67.4	70.22	29.32	37.464	67.2	67.8	69.25	68.4	81
1.5	51.26	71.8	58.44	27.7	28.934	66	66	68.8	68.4	72
2	52.62	72.74	71.3	30.986	41.43534	66.6	68.4	70	72	79.2
2.5	53.82	74.6	87.4	29.998	55.738	62.2	65.2	66.8	65.6	71.4
3	44.68	71.66	94.34	28.31	59.86	64	60.6	65.4	65.2	75.2
3.5	44.58	73.04	73.64	26.17	43.882	73.4	64	68.6	67.8	78.4
4	57.36	77.8	56.26	33.624	33.492	65.2	66.2	63	69.2	74
4.5	57.925	73.275	59.55	36.31991	40.60804	75	74	79	79.25	82.75

DI, DP and RQI Data for Composite Pavements (continued)

CS-49022w

M.P.	DI			DP		RQI				
	'93w	'95w	'97w	'93w	'95w	'92e	'93e	'94w	'95w	'96w
0	12.04	7.18	9.98	6.744	0.893462	37.8	41	42.8	45.4	47.2
0.5	7.16	13.94	19.5	1.9	4.102	31.8	32	32.4	41.4	44.2
1	25.46	33.08	50.38	16.39	18.30849	38.8	40	42.4	48.4	48.8
1.5	12.04	18.66	34.82	4.92	7.612	35	38.2	45.2	49.6	51.4
2	20.1	28	49.62	8.246	11.006	41.4	40.6	40.8	45	48.8
2.5	21.12	25.1	65.18	9.016	10.136	36.6	36.6	37.4	43.2	46.2
3	36.54	33.84	127.36	20.936	15.546	33.4	33.8	36.8	45	46.4
3.5	22.04	23.86	52.06	7.632	6.662	38.8	38.8	39.2	45.6	49.2
4	37.9	34.76	169.86	21.992	14.824	39	38.6	42.6	47.8	52
4.5	40.075	39.55	165.15	23.962	23.20778	39.5	41	39	46.75	50.25
5	10.54	12.2	29.92	3.74	2.958	40.4	42	45.6	51	52.4
5.5	8.5	8.75	17.24	1.69	0.5	44	38	41.2	47	49.6
6	7.05	13.03333	16	2.94	4.056911	34.2	29.8	42	48.6	51.4
6.5	6.1	12.98	20.36	3.006	4.094	27.8	28.8	31.8	41.2	45.4
7	39.08	44.12	175.66	24.744	28.364	34.4	39.2	39.6	47.2	52.8
7.5	16.9	25	82.16	2.152	12.05	29.2	34	34	44.4	46.6
8	30.48	33.72	112.64	23.354	19.72	36.8	39.6	47.8	57.6	58.6
8.5	15.82	23.12	60.34	11.182	13.312	30.4	33.6	41.6	48.8	54.6
9	16.66	21.12	41.9	12.468	12.508	26.6	27.4	45.4	52.4	59
9.5	7.42	10.26	20.08	4.452	4.57	29.4	32.8	41.8	46	47.4
10	5.14	8.46	10.54	2.274	2.524	35	37.6	39	44.2	44
10.5	33.62	48.9	217.36	13.496	29.206	40.8	46.33333	51.8	63.2	62
11	94.56	65.34	392.1	29.282	42.936	43.2	49.6	57.4	69	70
11.5	59.675	58.6	416.675	25.874	31.93113	41	48.75	48.75	56.5	62.25
12	75.52	49.16	327.28	39.064	24.91	49.8	53.8	50.6	58.4	61

DI, DP and RQI Data for Composite Pavements (continued)

CS-53022w

M.P.	DI			DP		RQI				
	'93w	'95w	'97w	'93w	'95w	'92e	'93w	'94e	'95w	'96w
0	21.6	45.075	50.225	12.96187	20.9875	63.6	64.8	63	64.5	70.4
0.5	16.5	31.38	52.52	12.268	19.392	59.2	56.2	51.6	60.8	61.8
1	19.12	37.98	57.12	14.29	24.334	60.2	52.4	59.8	57.4	67.8
1.5	24.72	39.58	70.7	17.22	25.482	57.8	53.2	55.6	58.8	64.8
2	18.22	28.18	47.26	13.752	21.336	54.8	49.2	53.4	56.6	61.6
2.5	13.22	27.74	39.62	11.036	20.954	56.8	51.4	61.6	59.2	66.8
3	13.88	30.28	43.38	7.396	15.424	56.6	54.6	58.8	61	66.6
3.5	16.2	35.9	65.82	11.666	24.072	45.4	52.4	49.8	59	55.6
4	14.98	26.84	42.7	8.462	17.836	38	50	40.6	55.4	50
4.5	12.06	30.32	41.36	7.328	19.732	41.4	45.8	46.6	53	52.8
5	13.42	34.16	43.5	9.47	21.118	41	41.2	47.2	47.8	54.2
5.5	13	36.56	46.36	6.266	22.026	37.8	42.6	41.4	51	50.2
6	19.34	43.1	58.88	11.5	27.562	44.4	53.4	50.2	59	59.8
6.5	11.88	31.6	50.08	10.636	21.25	42	49.2	44.4	57.4	55
7	9.8	26.58	43.68	9.264	20.126	40.8	47.6	36	55.4	48
7.5	9.32	26.84	39.44	6.582	17.322	44.2	41.6	56.8	48.4	59.6
8	12.12	24.5	32.02	10.314	20.574	51.5	56.25	53.25	58.5	65
8.5	12.72	26.74	47.28	8.148	19.028	46	41	50.8	49.4	56.6
9	18.08	36	61.22	9.054584	15.648	42	47	45.2	50.4	56.6

CS-81063e

M.P.	DI			DP		RQI				
	'93e	'95e	'97e	'93e	'95e	'92e	'93e	'94e	'95e	'96e
0	12.1		16.52	4.068		40.6	41.6	41.4	12.1	35.2
0.5	19.44		9.16	8.778667		37.4	38.8	39.6	19.44	49.6
1	35.54	N.A.	7.66	9.167611	N.A.	51.8	55	55.2	35.54	46.6
1.5	26.52		15.88	15.526		47.2	46.6	49.6	26.52	46.6
2	18.55		18.25	9.630494		45.75	54	55.25	18.55	48.25
2.5	11.52		20.88	2.184		48.8	52.6	55	11.52	50.4

DI, DP and RQI Data for Composite Pavements (continued)

CS-55011n

M.P.	DI			DP		RQI				
	'92n	'94n	'96s	'94n	'96s	'92n	'93n	'94n	'95n	'96s
3.5	4.42	3.36	20.44	0	9.254	22.8	21	22.8	28.4	34.4
4	2.44	5.54	18.08	0.376	6.694	24.2	23.4	25.2	31.6	32
4.5	1.2	6.98	15.6	0	6.434	28.4	26.8	27.2	33.2	37.4
5	0.6	4.4	12.7	0.376	5.178	29.8	25	28.4	35.8	36.4
5.5	0.14	3.62	12.14	0	6.026	21	20.4	23.4	29.6	36.8
6	0	1.3	12.9	0	5.244	22.2	22	26.2	32.8	31.2
6.5	0	0.48	11.04	0	7.28	23	23.2	22.2	28.6	29.4
7	0.18	1.38	11.6	0	5.67	23	23.4	25.4	31	29.6
7.5	0.24	1.08	14.96	0.188	9.024	19.8	19	19	25.8	26.2
8	1.1	0.62	11.8	0	5.602	22	22.8	25.4	31	29.6
8.5	0	0.82	16.56	0	6.586	17.4	16.8	17.8	25.2	28.4
9	0.78	3.68	17.5	0	9.52	21.25	20	29.5	25	27
9.5	1.12	3.18	25.3	0.05	15.492	25.8	28.6	31	39.4	42.4
10	0.333333	1.2	20.56667	0	9.63	18.8	18.4	18.4	27.2	27
10.5	0.425	2.725	17.075	0.4375	7.62	16.2	17.6	17.6	26.6	30.6
11	2.34	2.52	20.66	0.95	10.844	20.6	20.2	23.4	32	26.6
11.5	7.625	8.5	25.85	4.8625	12.85	21	21.4	22.6	30	31
12	2.54	4.6	15.28	2.292	13.012	21.8	22	22.4	29.8	29.8
12.5	0.65	3.225	16.5	0.5625	8.045	13.8	12.4	15.4	28.6	31.8
13	2.175	7.425	14.825	4.705	7.1375	21.2	20.6	23.6	31.4	34
13.5	0.25	1.475	9.575	0.5	2.9775	18.8	19	18.2	27	28.6
14	2.9	2.34	13.22	1.25	5.818	14	15.2	19	28.2	31.2
14.5	7.76	4.8	20.06	2.588	10.02	17	16.8	20.6	25.4	37
15	6.12	5.56	22.3	1.95	11.872	21.4	24	25.8	32.8	38.8
15.5	2.3	3.8	19.08	1.8	10.174	26.2	24.8	26.8	36.5	39.2
16	2.84	4.84	19.96	1.324	11.526	18.4	21.4	27.8	32.6	35
16.5	4.54	1.94	17.44	0.65	8.178	15.8	16.6	19	32.2	35.4
17	4.85	3.3	17.1	0.6875	10.4625	21.2	27.8	26.4	35	38
17.5	4	1.18	10.12	0	4.548	16.2	16.6	18.8	26.4	26.2
18	5.04	2.92	14.76	1.788	8.828	26.4	27.8	30.8	36.4	34.2

CS-55011n

M.P.	DI			DP		RQI				
	' 92n	' 94n	' 96s	' 94n	' 96s	' 92n	' 93n	' 94n	' 95n	' 96s
18.5	4	0.575	14.25	0	7.145	17.6	17.6	18.2	28.2	28.8
19	1.32	2.34	13.7	0.588	8.572	34.6	34.2	35.4	38.6	39.2
19.5	0.04	1.36	21.28	0.2	12.664	25.6	27.6	28.2	34	31.4
20	0	1.38	18.9	0	9.556	24	23.8	27.6	34	30.6
20.5	0.4	4.58	34.08	2.472	22.496	24	24.2	24.6	32.8	35

DI, DP and RQI Data for Composite Pavements (continued)

CS-58032e

M.P.	DI			DP		RQI				
	'92e	'94e	'96e	'92e	'96e	'92e	'93e	'94w	'95e	'96e
0	49.78	29.22	63.3	34.04863	51.756	73.4	77.8	66.8	72.8	73.4
0.5	60.91667	39.65	33.15	46.02145	7.644	75.25	77.25	73.5	71	74.25
1	41.65	38.98	55.05	26.11031	28.896	78.5	80.75	74	68.33333	74
1.5	46.2	68.64	97.56	31.722	60.334	61.4	66	70.8	66.4	67.4
2	43.12	57.8	82.7	28.97	48.378	56	60	65.6	61.6	60.8
2.5	41.38	59.14	87.34	26.482	49.454	60.8	61.2	66.8	62.6	62.6
3	38.28	56.44	95.64	27.056	55.444	68.8	71.4	74.6	67	69
3.5	38.32	54.48	98.24	22.924	51.862	58.2	61.8	61.4	58.6	61.8
4	44.08	53.78	109.4	22.14	53.356	61.4	62	63	61.2	61.8
4.5	42.12	65.72	129.32	23.734	72.902	59.6	64	66.4	61.4	63.2
5	48.2	69.06	119.42	26.774	73.562	59	62.8	67.2	62	64
5.5	54.02	74.875	122.775	26.57657	68.93	63.6	67.6	63.4	62.4	61.8

DI, DP and RQI Data for Composite Pavements (continued)

CS-63173n

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0	12.8	35.24	25.8	4.426	13.908	42.6	57.25	50.6	49.6	49.4
0.5	6.6	29.3	24.66	2.616	13.434	44.6	55	50.6	49	49.6
1	8.38	44.24	35.9	4.952	27.58	38.4	58.4	46.4	49.2	47.6
1.5	11.7	46.65	39.525	3.892539	28.58861	42.75	51.2	46.25	48.75	47.75
2	9.14	38.22	32.78	5.226	20.43	43.2	43.2	51.2	50.6	52.8
2.5	10	36.46	27.2	4.172	23.748	43	41.8	50.8	45	45.4
3	12.42	26.48	27.8	2.266	16.482	43.4	48	52.2	46	44.2
3.5	9.4	7.92	23.14	4.77	6.026	39.6	54.4	49.8	51.8	53
4	8.78	8.52	27.54	3.072	7.122	52	58.6	62.4	53.4	50.6
4.5	12.64	8.58	29.2	3.634	7.416	49.8	52.2	57	52.4	56.8
5	16.52	13.68	32.54	5.918	10.06	53.2	49.6	60.2	55.2	54
5.5	13.46	6.6	29.36	3.746	5.626	49.8	46.2	60	56.8	58
6	8.14	7.52	28.06	4.234	4.824	47	49.2	55.4	51.2	56.4
6.5	12.06	6.16	26.32	3.618	4.342	52.2	45.8	56	54.8	60.6
7	8.42	5.72	25.8	4.05	4.6	48.6	54.8	55.6	51.2	61.6
7.5	7.6	6.24	24.14	4.274	5.192	45.4	50.8	54.6	47.2	45.6
8	8	9.26	25.02	4.984	6.028	51.2	42.2	56.8	47.8	54.4
8.5	7.7	11.64	25.62	5.394	8.916	36.2	58.2	54.6	49	59.6
9	10.18	6.72	22.58	7.042	5.004	48.8	54.4	58.4	55.6	62.4
9.5	11.6	6.84	18.58	6.494	5.132	49.2	55.8	64.2	56.8	61.8
10	14.34	10.66	14.38	8.804	8.372	46.2	52	67	60.8	65.8
10.5	7.48	6.32	14.9	4.474	4.93	46	51	57	59.4	58.6
11	8.04	7.64	21.78	4.146	5.154	39.2	45.2	50.8	55.4	55
11.5	7.9	7.46	19.72	3.808	4.812	32.8	44.8	46.6	51.8	52.6
12	7.42	6.2	18.18	4.684	4.346	35.8	50.2	53	51.6	51.2
12.5	9.76	8.92	22.12	6.964	6.938	40.6	40.25	61.4	55	58.2
13	8.48	9.56	13.5	5.324	7.744	38.8	44.4	55.6	54.8	50.8
13.5	7.5	8.7	16.04	3.432	6.394	38	50.6	55.4	53.4	54
14	7.8	10.6	20	2.504233	7.125015	57.66667	46.4	65.33333	44	45

DI, DP and RQI Data for Composite Pavements (continued)

CS-73111n

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0	1.36	9.62	7.26	0	2.93	30	26.5	29	36.5	42.8
0.5	3.24	9.6	9.76	0	5.24	34.6	33	35.2	40.8	46.6
1	4.02	7.66	11.98	0.188	5.146	32.2	33.4	35.6	39.6	44
1.5	4.12	10.6	10.28	0	5.17	25.8	28	31.2	36.6	41
2	5.24	7.92	7.04	0.588	4.24	30.6	31.4	34.2	41	46.8
2.5	3.94	6.08	6.7	0	4.604	29.2	31	33	38.2	43
3	4.74	8.94	7.02	0.188	6.598	32	32.2	34.4	40.4	44.8
3.5	11.48	14.88	12.76	0.586	8.402	33.4	35.8	41.4	47.2	52.6
4	3.375	8.075	7.466667	0	3.91125	30.5	30.25	32.5	36.75	40.25
4.5	5.12	8.7	7.16	0	3.418	33.4	32.8	36	41.6	46.2
5	6.86	12.24	10.48	0.188	4.792	33.6	36.2	40.2	45	47.8
5.5	7.96	13.36	13.18	0	7.174	39.8	39.6	45.66667	47.2	52.4
6	8.46	11.82	11.98	0	5.996	33	33.8	39	44.6	48.8
6.5	5.6	12.075	12.725	0.288535	5.08894	35.25	35.75	36.75	41.25	47.75
7	6.58	15.12	15.6	0.196	6.658	36.6	35.8	40	43.6	50.4
7.5	6.66	16.2	14.72	0.376	8.092	34	33	38.6	43	48.8
8	4.275	13.175	14.23333	0	5.366835	41.25	41.5	41.75	38	43.33333

DI, DP and RQI Data for Composite Pavements (continued)

CS-75022

M.P.	DI			DP		RQI				
	'93w	'95w	'97w	'93w	'95w	'92e	'93e	'94w	'95w	'96w
0							61.8	60.6		71
0.5			N.A.				45.2	42.6		52.8
1							60.4	50.6		55
1.5	20.18	25.92	30.34	1.448	11.192		67.6	59		66.5
2	22.9	23.36	36.3	2.476	8.732		67.6	51		71.6
2.5	16.7	38.16	26.34	5.258	22.092		67	64		76.6
3	20.32	54.52	41.18	8.376	39.724		56.8	48.8		61.6
3.5	32.225	55.425	86.04	8.288	17.5		33.4	34.4		44.8
4	32.125	38.24	98.425	4.71	19.842		37.2	30.8		44
4.5	26.04	27.44	37.96	3.85	11.708		35.2	40.4		50
5	18.22	23.3	23.6	4.41	10.31		38.2	38		47.4
5.5	21.86	26.82	22.44	4.582	11.886		30.8	27		39.8
6	16.92	18.98	21.08	4.95	9.16	N.A.	33.8	28.6	N.A.	37.6
6.5	14.8	20.68	19.28	3.484	9.758		36.4	41.2		49.2
7	16.94	25.44	21.28	3.888	10.92		34	41.6		50
7.5	17.7	28	20.1	5.602	15.026		37.6	44.2		50.8
8	21	23.4	26.42	7.104	11.182		36	41.2		48.8
8.5	17.3	22.34	25.36	6.216	11.588		34.4	46		58
9	9.98	24.22	23.16	3.2	13.294		29.4	38		45.2
9.5	16	30.425	28	5.908	17.245		39.4	43.6		54.6
10	10.04	35.9	36.2	4.43	33.27		43.6	49		54.8
10.5	18.68	39.14	58.3	11.154	22.196		44	49		56.4
11	24.76	42.92	37.84	14.304	23.978		37	45.4		51.6
11.5	27.6	35.22	48.08	13.106	19.12		37.6	39.4		48.4
12	28.22	24.36	34.16	13.716	13.408		41.2	47		49.2
12.5	25.7	21.12	26.86	14.228	12.862		43.8	39.6		32
13	16.5	12.68	20.1	8.238	5.894		32.2	29.4		27.6

DI, DP and RQI Data for Composite Pavements (continued)

CS-76062w

M.P.	DI			DP		RQI				
	'92w	'94w	'96w	'94w	'96w	'92e	'93e	'94w	'95w	'96e
3	5.46	13.94	39.7	5.808398	22.616	75.8	75.2	54.4	73	79.6
3.5	7.56	18.28	36.56	4.252	22.312	78.4	77.6	30.6	77	83.2
4	13.66	26.42	44.12	6.266	28.11	80.4	80.8	36.6	85	89
4.5	9.54	25.52	36.02	9.134	19.006	83.2	90.2	40.6	89	94.2
5	3.7	15.46	27.56	4.964	13.284	76.4	78.6	36.8	84.4	85.2
5.5	6.44	19.58	38.02	9.154	23.766	76	79.8	39	81.4	85
6	5.48	17.72	33.76	6.572	17.306	69.2	72.6	40.8	76.2	81.6
6.5	11.32	26.46	53.2	13.724	35.826	72.4	75.4	49.8	75.4	81.4
7	6.6	15.44	38.74	5.974	24.436	69	71.4	48.6	73.2	84.2
7.5	14.14	22.76	52.08	8.888	31.368	72.2	73.4	51.4	76.6	84.4
8	14.16	20.58	40.8	6.3	23.776	76.4	82.8	54.2	81.6	84.8
8.5	10.68	18.72	37.32	6.262	20.134	80	81.2	47.6	76.8	86
9	9.48	16.18	32.98	4.948	19.29	72.8	74.2	48.6	71.8	75
9.5	6.38	13.06	35.3	3.692	18.758	65.2	66.2	44	70.2	72.4
10	9.44	17.48	42.24	4.508	26.32	70.4	70	43.6	68.2	73.6
10.5	6.24	13.08	37.04	4.436	24.02	70.8	71.8	47	69.4	71.8
11	9.18	15.02	44.38	5.28	31.402	52.8	53.6	47	52.6	60.2
11.5	4.32	10.66	24.08	4.158	14.736	40.8	43.4	41.2	45	56.2

DI, DP and RQI Data for Composite Pavements (continued)

CS-78012

M.P.	DI			DP		RQI				
	'93s	'95s	'97s	'93s	'95s	'92s	'93s	'94s	'95s	'96s
0		36.32	61.05		11.58831	37	39.2	44.2	48.2	44.75
0.5		38.16	72.8		9.316	28	30.2	35.8	41.8	41.2
1		40.86	68.38		13.906	28	30.8	35	41.6	41.6
1.5		37.76	52.6		13.166	27	29.2	37.6	38.2	43.4
2		28.68	49.7		10.531	47.8	51	56.6	53.4	54.4
2.5		3.08	17.96		0	83.6	90.8	89.8	56.4	54
3		4.86	16.1		0.188	66	67.25	76.5	57.8	51.25
3.5		17.9	32.875		8.294	44.8	48.4	50.6	50	58
4	N.A.	31.42	49.56	N.A.	19.244	36.6	40.8	52	50.2	51.4
4.5		30.34	42.56		13.708	39	41	44.4	49.6	53.4
5		38.86	57.54		25.19	46.2	52.8	60	56.6	63
5.5		43.74	63.8		27.444	49.8	56.8	65	57	62.4
6		41.4	60.68		27.68	43.4	49	55.2	60	58.8
6.5		43.6	60.22		28.602	45.8	56	58.8	60.8	61.2
7		58.72	77.66		40.124	43.4	53.6	57.4	60	61.4
7.5		41.58	59.62		28.688	40.6	49.6	53.4	54.4	57.6
8		45.78	65.44		29.644	44	50.8	57.2	57	56.2
8.5		44.7	75.28		31.424	46.2	51.6	55.2	60.8	60.8

DI, DP and RQI Data for Composite Pavements (continued)

CS-82194n

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0	27.46	44.7	28.5	7.764	15.23	69	78	84.2	75.2	71.25
0.5	23.32	48.78	27.56	7.941542	12.35081	59.6	64.8	66.8	73.6	69
1	45.65	73.15	84.275	16.28	18.70101	79.75	90	88	89.8	92.5
1.5	38.86	52.6	59.34	9.884	13.474	66.4	80	74	79.8	84
2	80.6	35.375	66.45	16.11215	9.989395	69.33333	69.33333	73	76	75
2.5										
3					Bridge					
3.5										
4										
4.5	49.9	58.225	47.15	14.44333	11.095	67.4	78.2	79.2	75.2	81.33333
5	45.38	55.88	38.08	6.694	7.464	58.4	73	72.4	77	74
5.5	63.58	58.18	12.84	15.08	14.914	77.8	87.4	85	84.6	74.4
6	38.06	47.42	32.7	9.502	13.36	76.4	84.8	83	88	78.4
6.5	38.6	46.64	43.98	12.02938	12.888	80.4	84.4	86.6	84.2	86

CS-63091n

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0	34.68	40.16	108.46	17.806	21.778	94.4	98.4	102	96.66667	93.33333
0.5	39.8	51.44	101.02	26.132	33.644	94.4	98.4	100.4	100.2	101.6
1	13.22	20	57.36	6.614	10.282	73.6	76	80	86.5	74.5
1.5	18.08	21.54	48.92	11.82	14.064	65	70.8	71.4	71.8	65.25
2	24.78	28.94	54.16	11.528	16.06	71.8	76.6	81.2	73.4	77.8
2.5	44.18	44.36	163.48	21.342	25.844	71	74	79.8	79.4	71.8
3	40.68	35.58	79.44	26.61	25.736	82.2	89	87	87.5	84.5

DI, DP and RQI Data for Flexible Pavements (continued)

CS-09101e

M.P.	DI			DP		RQI				
	'93e	'95e	'97e	'93e	'95e	'92e	'93e	'94e	'95e	'96e
1	3.96	13.16	20.2	0	1.154	34.6	33	33.8	37.4	45.2
1.5	2.84	29.86	49.16	0	3.748	30.6	30.6	32.4	37.6	49.2
2	4.56	36.74	40.8	0	3.192	34	33.8	33.2	39.2	49.8
2.5	3.52	43.94	43.26	0	2.834	20.2	20	23	30.2	42
3	3.96	40.96	40.96	0	4.802	31.8	29	31.2	36	43.4
3.5	3.04	33.84	29.16	0	3.534	26.8	25.8	27.6	36.2	45.8
4	1.98	37.2	22.58	0	4.726	20.8	20.6	23	32.8	43.8
4.5	1.16	37.48	33.66	0	8.538	27.8	27.4	33.6	34.6	45.2
5	1.68	30.36	30.16	0	3.246	34.8	35.4	34	41.8	50.2
5.5	1.28	14.12	24.52	0	1.508	34.2	32.8	32.6	37.2	47.4
6	3.688889	16.64	31.94	0	2.348	38	36.2	35.2	41.2	50
6.5	3.844444	11.72	20.7	0	0.78	35.4	32.2	32.2	36	44.2
7	1.533333	8.42	17.68	0	1.492	32.6	31	29.6	35	42.6

DI, DP and RQI Data for Flexible Pavements

CS-11015e

M.P.	DI			DP		RQI				
	' 93e	' 95e	' 97e	' 93e	' 95e	' 92e	' 93e	' 94e	' 95e	' 96e
0	4.2	34.525	2.5	1.679815	11.88519	27.66667	36	27.66667	35.66667	41.33333
0.5	3.06	35.1	1.62	0.586	13.886	24.2	23.2	25.2	32.6	32.2
1	2	34.84	0.66	0.2	12.742	28.8	27.4	27.8	33.8	30.2
1.5	3.325	30.2	2.65	0.97819	14.05869	34.75	24.33333	35.25	35	38.66667
2	2.1	16.88	1.9	0	5.21	17.6	17.8	19.6	28.8	44.6
2.5	1.4	5.82	1.14	0.188	0.898	40.4	37.2	42.8	46.4	58
3	0.3	4.86	0.66	0	0.784	34.8	35.4	36.8	41.8	60
3.5	2.22	2.44	0.58	0	0.388	20.8	19.8	21.6	29.2	42.6
4	1.34	1.04	0.08	0	0	32	30.2	30.8	36.8	48.2
4.5	1.08	1.34	2.26	0	0	31.8	31.8	33.8	37	51.6
5	0.44	1.54	0.78	0	0	30	29.8	29.6	39.6	59
5.5	0.24	1.04	1.34	0	0	29.8	26.6	28.2	35.8	54.6
6	0	1.46	0.6	0	0	31.4	27.6	29.2	39.8	53
6.5	0.22	0.66	0.02	0	0	27.8	33	26.4	34.4	51.2
7	0.16	0.78	3.14	0	0	41	34.4	36.2	45.2	58.2
7.5	0.18	2.64	1.56	0.143836	0.988076	26.2	29	32	38.2	51.6
8	1.566667	2.033333	0.6	1.055726	1.055726	35	51.66667	39.33333	42	34.5
8.5	0.96	4.34	1.04	0.21	0.762	26	28.6	29	36.2	38.4
9	1.06	3.84	0.82	0	0.574	24.2	22	22.4	31	33.2
9.5	0.52	5.56	2.06	0	0.288	23.8	23.4	22.2	32	31.6
10	1.96	2.3	1.9	0.384	0.188	28.4	24.6	25	33.8	35.8
10.5	1.96	1.84	2.08	0	0	24.6	21.2	29.6	30.6	33.4
11	0.66	2.94	1.9	0	1.03	31.2	31.4	28.6	39.8	34.4
11.5	0.9	3.18	0.84	0.350909	1.224759	36.2	35.5	30	40.25	34.75
12	0.5	3.35	3.2	0.514	0.7175	26	35.8	38	36.25	39.5
12.5	3.4	5.4	1.125	0.661364	2.023071	29.75	27	29.75	38	47
13	2.08	1.8	1.12	0.386	0.996	17.2	20	17.2	25.6	38.2
13.5	3.175	2	2.225	0.740521	0.984149	15.25	16.75	16.75	28.25	38.75
14	2.98	0.24	3.72	0	0	20.4	15.8	16.4	28.8	43.6
14.5	2.32	1.84	0.54	0	0.6	22.2	19.6	21.4	34.4	43.6
15	2.28	1.3	0.6	0	0.388	20.6	21.2	21	33	40.8

CS-11015e

M.P.	DI			DP		RQI				
	'93e	'95e	'97e	'93e	'95e	'92e	'93e	'94e	'95e	'96e
15.5	1.52	0.48	0.7	0	0	20	15.4	16.4	27.8	42.4
16	0.34	1.24	0.54	0	0.2	24.2	21.8	23.4	31.8	42
16.5	0.5	0.86	1.02	0	0	16.2	18	18.4	26.4	43.4
17	0.8	0.46	0.44	0	0	20.2	25.5	21.6	29.6	41.6
17.5	0.84	0.7	0.1	0	0	25	24.4	32.33333	32.4	38.8
18	0.82	0.72	0.84	0	0	17.4	16.2		30.2	39.6
18.5	1.08	0.8	1.35	0.575189	0.216942	33	34.5		30.66667	42.66667

DI, DP and RQI Data for Flexible Pavements (continued)

CS-11111n

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0	25.72	86.225	114.775	6.024	58.975	61	68.75	63.75	76	76.25
0.5	32.72	133.36	234.62	9.964	100.15	80.6	87.2	79.6	85.4	85.6
1	33.96	100.14	167.72	17.514	63.544	75.4	82.8	78.6	78.4	78.8
1.5	37.64	129.3	200.52	5.958	91.83	82.6	87	82	77.6	80.2
2	44.175	124.88	139.9	1.898759	77.38764	77.5	86	84.75	83.66667	85
2.5	42.52	122.86	84.68	5.6	87.238	67.8	79.2	75.8	79.6	81.8
3	32.8	137.48	89.46	5.454339	85.07733	69.6	80.2	74.4	84.2	86
3.5	36.9	109.4	181.55	3.377273	77.12104	64.33333	69.33333	68.66667	74.66667	72.33333
4	40	78.1	125.44	0.764	40.816	66	77.4	67.2	75.6	69.6
4.5	29.32	88.5	131.22	1.258	48.692	50	65.2	65.4	61.8	59.2
5	24.06	82.24	82.46	0.688	46.534	61.8	68.2	64.4	74	72.6
5.5	22.44	83.02	93.12	1.074	48.902	45.6	52.6	47	62.2	54.8
6	29.3	102.92	94.98	2.02	61.62	41.8	47.8	40	57.4	59.4
6.5	34.6	102.78	324.36	4.188	65.06	53.2	65.8	55.6	69	71
7	38.4	114.04	237.84	3.346	73.972	47.2	54.2	48.2	56.66667	51.4

DI, DP and RQI Data for Flexible Pavements (continued)

CS-14041

M.P.	DI			DP		RQI				
	'93e	'95e	'97e	'93e	'95e	'92e	'93	'94w	'95w	'96w
9	183.78	218.74		59.606	45.826	51.4		60.6	65.6	70
9.5	111.66	148.98		67.98	60.772	47.6		55.2	67.8	67
10	103.62	132.96		43.836	43.672	39.8		51.6	62.4	63.4
10.5	83.44	86.04		48.352	43.204	55.6		60.6	74.2	75.6
11	104.76	97.38		60.06	51.366	53.2		67	73.4	72.4
11.5	86.58	85.78		45.426	42.246	51.8		60.2	64.6	66.4
12	94.56	121.32	N.A.	51.24	47.432	51.2	N.A.	53.2	56.4	61.8
12.5	123.84	123.2		75.088	50.842	56.2		53	60.8	56
13	126.38	95.775		61.84667	35.858	53.75		63.75	59.25	66.4
13.5	132.06	82.7		82.66	49.916	61.8		67	73.4	72
14	130.28	79.36		71.154	45.006	65.4		71.8	78.8	75.75
14.5	163.62	124.82		99.9	67.148	62.2		66.2	71.25	74.8
15	131.88	85		72.892	43.104	52.8		61.2	65.4	65
15.5	160.525	94.9		100.6625	58.62	59.4		63	62.4	65.8

CS-20016n

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0	61.26	38.66	95.48	43.97	11.63	49.6	68	52.4	59.4	58
0.5	38.56	35.98	70.58	23.842	10.726	50.4	63.2	51.4	61.6	63.6
1	46.3	38.26	69.72	33.294	14.51	46.8	64.6	49.2	57.6	55.4
1.5	31.44	33.8	62.24	18.982	9.89	48.4	26.6	51.4	58.8	54.6
2	36.94	33.42	78.98	21.334	4.778	49	29.2	50.4	61.2	54.8
2.5	24.64	30.72	80.12	10.944	4.786	54.8	26	53.2	61.4	58
3	28.96	27.06	98.18	17.462	2.666	52.2	26.4	52	56	55
3.5	53.34	34.6	177.92		7.828	51.8	25.4	51.8	55.6	58
4	64.54	28.8	104.96	45.754	3.004	55.4	53.2	61.2	56.6	57.2
4.5	44.4	38.3	78.04	34.06	8.932	54.4	61	59.6	62.4	59.8
5	48	49.5	128.7	31.24	13.798	52.8	66.6	56.6	55.4	51.6
5.5	77.76	59.96	124.74	50.87	26.944	73.8	66.6	76	77.2	73.8

DI, DP and RQI Data for Flexible Pavements (continued)

CS-21032

M.P.	DI			DP		RQI				
	'92s	'94s	'96n	'94s	'96n	'92n	'93s	'94s	'95s	'96s
10.5	62.18	56.65		38.65967		61	69	72.4	63.4	66
11	49.88	51.48		32.094		68.4	70	71.6	74.4	74
11.5	66.7	62.86	N.A.	51.22	N.A.	66.2	62.2	67.2	68.8	71.2
12	72.58	57.16		38.414		60.6	75	80.6	82.2	83.6
12.5	42.16	42.46	89.28	25.816	51.056	56.8	60.4	65.6	68.4	69.8
13	66.52	56.04	73.64	39.4	37.448	57.6	70.4	75.4	77.8	75
13.5	78.02	82.7	97.94	60.722	64.644	55.4	61.4	67	69.4	66.2
14	73.84	94.62	115.1	70.016	86.612	50	55.6	59	61.4	64.4
14.5	70.42	92.24	134.42	75.926	104.344	39.2	48	50.6	52.8	55.8
15	84.92	98.96	109	78.378	79.214	42.2	57.8	60.4	63.8	62.6
15.5	60.86	79.06	112.08	58.178	79.352	45	49.2	50	55.6	56
16	108.96	111.2	140.72	95.222	101.032	44.4	62.6	62.2	64	62.4
16.5	64.8	61.54	130.82	34.074	50.452	58	71.2	76.4	80.2	82.4
17	47.02	48.66	126.32	24.77	36.886	58	63.2	67.4	69.4	70.6
17.5	28.96	36.72	209.3	18.09	29.352	58	62.8	64.2	65.8	68.6
18	39.44	44.34	74.36	18.96	21.668	63.4	70.8	71.8	72.2	77.2
18.5	55.72	55.2	136.68	31.994	29.308	65.8	65	68.6	72	70.6
19	32.32	34.06	172.86	10.298	41.664	59.2	49.8	53.4	57.4	59.2
19.5	35.88	39.28	88.28	18.842	26.258	70.4	67.2	69.2	70.4	71.6
20	58.2	72.22	69.9	29.198	31.966	58.2	59.6	59.8	62.8	64.4

DI, DP and RQI Data for Flexible Pavements (continued)

CS-22013

	DI			DP		RQI				
M.P.	'92n	'94n	'96s	'92	'94	'92	'93n	'94	'95n	'96s
0	45.86	72.56		38.512	52.262	52.6	58.6	61	66.6	35
0.5	65.34	101.74		51.192	76.254	55	63	65.2	69	33
1	22.02	25.9		14.222	12.894	50.4	51.4	55	57.8	32.4
1.5	20.48	23.92		14.1	10.656	42.2	48.4	50.2	51.2	30.8
2	28.06	34		23.35545	18.62083	47.2	50.4	53.6	54.4	25.8
2.5	24.84	31.44		14.22167	19.845	61.2	55.5	63	63	34.25
3	38.56	51.66		24.71934	28.1827	42.4	57	59.6	63	33.2
3.5						69.8	71.8	74.4	74.2	42.6
4	44.5	54.18		34.10667	33.01333	57.4	67.6	71.2	76	34.2
4.5	13.4	19.12		9.11	9.794	44.6	35.5	50	47	32.75
5	11.24	17.82		7.114	8.676	47	47.8	50.8	56.2	30
5.5	19.82	31.04		12.17	14.79	51.6	51	54.6	60	30.6
6	13.1	20.22	N.A.	7.384	11.166	51	49.8	52.2	57.2	29.4
6.5	32.18	51.18		27.014	40.27	59.8	58.2	64.4	68	32.4
7	18.04	24.78		12.398	13.496	53.8	55.8	58.4	61	30
7.5	18.16	26.14		12.832	15.656	51.4	53.4	56.2	59.4	31.4
8	25.12	37.78		19.93	26.522	46.4	54	57.4	59	27.4
8.5	16	29.52		12.136	21.536	67	70	72	75.2	29.2
9	31.58	46.42		25.248	35.014	63.4	73	76.6	78.2	40
9.5	86.26	131.66		72.108	104.666	40.6	48.8	50	59	33.2
10	69.4	121.92		54.382	79.738	50.6	51.2	53.2	59.6	33.6
10.5	50.82	92.7		39.126	46.71	59.6	59.8	63.2	67.6	35
11	43.94	63.36		30.642	36.962	57.4	60	64.2	68.8	35
11.5	56.16	74.9		41.582	54.788	60.8	69.8	74.6	79.4	30.6
12	45.38	67.4		30.632	35.2	59.2	58.2	64.8	66.6	33.2
12.5	53.76	91.02		36.18373	49.42948	56.8	58.6	63.4	65.4	34.4

DI, DP and RQI Data for Flexible Pavements (continued)

CS-25102

M.P.	DI			DP		RQI				
	'92e	'94w	'96e	'92e	'96e	'92e	'93w	'94e	'95w	'96e
0.5	26.18	44.26	107.44	7.08	30.7	42.2	36.6	50.8	46.8	61.8
1	31.08	60.88	96.72	15.02	47.32	41.2	44	45.2	46.8	51.2
1.5	31.84	77.16	88.22	14.948	60.532	34.4	40.2	33.6	43.4	44.4
2	45	82.8	143.96	24.726	63.868	33.2	35.8	35.8	41.8	40.2
2.5	43.14	79.28	146.8	22.294	56.406	40.6	48.4	49.2	47.8	47.8
3	51.825	43.56	107.46	23.92771	66.026	49.2	49.2	51.8	51.4	58.8
3.5	56.82	43.66	84.34	30.15	53.688	46.8	43.2	52.8	47.8	56
4	63.96	69.1	104.92	25.914	58.424	46	45.4	56.2	49.4	58.6
4.5	87.22	86.88	168.02	58.392	97.216	43.2	38.6	49.8	52.2	60.4
5	73.16	101.74	140.5	45.63	79.166	45	53	58.8	60.2	65.8
5.5	50.8	66.92	102.72	30.082	63.172	51.8	50.6	59.2	58.6	67
6	12.44	44.38	48.48	1.56	33.578	38.4	31.8	33.4	41.2	43.2
6.5	11.76	43.1	32.66	1.408	21.988	28.4	27.8	32.2	43.2	40.4
7	13.14	19.9	42.42	2.508	27.74	34.6	31.6	35	41.4	45.8
7.5	15.32	30.36	38.38	3.02	26.714	35.2	33	34.6	40.8	42
8	25.56	23	55.1	11.5	41.698	41.2	34.4	50	47.2	53.8
8.5	31.92	46.34	110.64	6.816	59.53	45.4	42	52	48	61
9	15.8	18.38	49.7	1.188	24.778	33.2	30.4	38.4	39.6	49

DI, DP and RQI Data for Flexible Pavements (continued)

CS-26032

M.P.	DI			DP		RQI				
	'92n	'94s	'96n	'92n	'96n	'92n	'93n	'94n	'95s	'96s
0	12.5	22.375	39.28	2.652	17.092	40.4	41.6	41.2	43.75	46
0.5	23.45	30.2	86.975	11.72973	44.36	35	36.25	36.25	43	44
1	18.52	28.26	55.16	4.174	28.638	31	32.8	33	40.2	41.6
1.5	10.66	16.98	44.56	2.864	22.83	34.4	35	35.8	41.6	40.4
2	8.08	22.36	40.22	0.396	12.432	26.6	28.6	31.6	39.6	37.4
2.5	7.76	24.14	42.96	0	17.49	30.2	31.4	32	37.4	36.8
3	14.02	51.28	97.52	1.898	31.782	36.6	37.6	39.8	42.4	46
3.5	7.72	31.05	30.64	2.695915	15.556	41.75	40.75	42	47.33333	50.33333
4	4.54	21.48	43.84	1.476	21.416	28.8	30	34.2	39.8	40.2
4.5	6.58	14.92	34.6	0.582	14.056	27.8	29	32.4	37.2	43.6
5	6.84	16.32	41.42	1.186	16.426	34.6	37.2	38.2	45.8	46.2
5.5	9.96	18.86	52.5	1.08	25.054	39.2	41.8	43.2	48.6	53.6
6	12.16	26.92	57.28	1.812	31.342	32.4	37.2	37.2	38.8	45.4
6.5	10.52	30.48	35.34	4.396	22	29.6	31.8	33.2	34.2	42
7	17.28	45.22	57.88	6.47	28.136	33.8	39.6	41.8	49.6	52.4
7.5	5.62	25.14	30.24	0	10.888	38.4	39.2	40	49.6	52.6
8	13.68	30.4	55.5	4.904	30.798	31	33.4	37.2	37.8	40
8.5	13.8	35.58	62.42	4.508	32.76	30.2	34.8	36.4	39.6	43.8
9	9.34	28.94	55.96	2.17	27.218	35	35.8	41	43	45.8
9.5	7	21.92	61.64	0.772	33.876	31.2	33.6	35.8	43.6	46
10	27.1	61.7	75.48	12.778	53.316	34.8	36.2	37.8	41	43.6
10.5	20.1	47.44	75.32	10.752	54.664	41.2	40.4	40.4	48	51.6
11	9.12	45.9	54	3.048	35.842	36	36.2	37.4	40.6	44.4
11.5	15.74	32.6	63.14	8.666	41.242	36.8	37.6	38.4	42	44.4
12	5.22	24.54	35.82	1.876	18.958	32	33	33.2	34.2	37.2
12.5	7.04	31.02	21.88	1.252	6.074	32.2	32.4	34.2	37.6	42.6
13	9.78	28.32	34.38	2.898	18.084	32	32.6	33.4	40	41.8
13.5	5.36	11.58	24.34	0.196	11.218	28.2	27.6	28.4	36	35.6
14	5.5	17.08	16.3	1.076	5.214	30.8	29.6	29.4	33.8	37.2

CS-26032

M.P.	DI			DP		RQI				
	'92n	'94s	'96n	'92n	'96n	'92n	'93n	'94n	'95s	'96s
14.5	2.06	12.9	20.38	0.982	9.154	33.2	30.8	29.5	37.6	41.4
15		18.5	23.65	1.245	10.515	40.5	41	52.66667	36.33333	42
15.5	4.88	25	31.56	0.492	9.91	35.2	33.8	36.2	40.6	42.2
16	43.8	59.22	79.7	21.888	53.798	30.4	31	33.4	48	45

DI, DP and RQI Data for Flexible Pavements (continued)

CS-29022

M.P.	DI			DP		RQI				
	'92e	'94w	'96e	'94w	'96e	'92	'93w	'94e	'95w	'96e
0	12.1	13.63333	47.91667	0.508333	7.802		44	40.6	38.5	42.4
0.5	24.6	17.28	183.38	1.476	13.63		21.8	32.8	31.2	45
1	19.08	21.36	135.9	2.622	13.636		38.2	38	42.2	48.6
1.5	17.64	12	110.32	0.514	7.676		30.2	29.8	39.2	41
2	15.26	6.32	44.04	0	2.124		26.2	27	33.8	38.6
2.5	15.46	7.12	59.48	0.304	5.394		23.4	30.8	31.2	38.8
3	9.46	42.26	78.64	11.584	8.260526		41.6	30.2	45.4	43.4
3.5	17.88	26.375	47.7	5.5	8.4675		37.25	32.5	44.25	43.75
4	18.06	11.9	90.26	1.414	4.44	N.A.	24	33.6	37.4	48.2
4.5	12.38	9.8	87.54	0.576	3.962		28.4	31	34	44.4
5	9.7	11.8	55.725	0.188	6.391429		26.33333	27.66667	37.33333	39.33333
5.5	6.94	6.8	21.5	0.346	1.61		22.8	30.6	31.2	38.8
6	7.3	20.44	19.56	1.498	2.536		23.2	27.8	32	37.8
6.5	9.5	23.64	31.92	0.504	2.26		31.6	26.4	37.4	36.4
7	5.22	23.76	26.62	1.64	2.19		34.6	26.8	40	36.6
7.5	6.16	16.8	29.56	2.732	2.288		28.4	26.8	36.8	36.6
8	9.34	29.82	48.16	9.302	4.226		35	27.8	45.2	36.2
8.5	4.02	12.44	33.26	0.788	1.874		25.8	26.6	32.6	34.2
9	5.04	12.02	8.3	1.292	0.556		24.6	29.6	29.8	39.2

DI, DP and RQI Data for Flexible Pavements (continued)

CS-31021

M.P.	DI			DP		RQI				
	'93e	'95e	'97e	'93e	'95e	'92e	'93e	'94e	'95e	'96e
0	4.58	5.56	7.7	2.342	2.748	31.6	36	38.8	41	42
0.5	8.28	17.7	29.46	4.498	8.308	26.6	31.6	34.2	39	42
1	13.42	20.9	46.74	7.176	12.278	27	33.8	38.2	43.4	47
1.5	8.6	12.3	25.66	1.28	3.132	25.2	26.8	31.4	35.2	41.8
2	24.14	33.22	55.5	8.768	11.116	26.8	30.2	34.4	41.4	47.4
2.5	91.14	63.64	130.74	62.54	40.68	34.8	42.4	51.4	56	61.2
3	25.02	31.38	49.8	10.39038	13.388	45	43.2	52	51.8	44.5
3.5	22.84	24.02	40.5	2.762	4.254	37.6	37	40.6	45.2	45.2
4	26.98	34.76	42.94	7.28	13.244	33.4	41.2	45.4	50.6	55.2
4.5	18.22	25.27	24.9	7.51175	9.643495	58.5	62.6	64.5	61.8	62.5
5	31.76	37.76	44.1	18.144	17.988	35	46.6	51.8	54.6	56.6
5.5	24.58	27.96	33.46	13.044	11.304	37.2	50.4	57.2	57	63.2
6	14.46	18.7	26.42	5.598	3.582	26.2	33.4	41	49.2	47.8
6.5	16.1	30.58	44.88	6.772	8.042	39.8	41.4	46	51	52.2
7	27.18	52.2	82.14	13.304	24.668	32.4	40.2	45.4	50.2	55
7.5	17.78	45.12	52.62	7.01	16.914	28.4	30.2	35.2	41.6	44.4
8	33.92	53.12	68.46	15.554	17.53	36	26.6	32.8	39.8	41.2
8.5	22.78	42.64	68	9.006	21.004	33.4	34	38.2	45	48.2
9	29.74	46.72	79.5	19.62	27.304	42.2	54.4	59.2	60	62.4
9.5	6.32	5.96	7.38	3.46	0.642	24.8	29.6	31.4	38.8	37.6

DI, DP and RQI Data for Flexible Pavements (continued)

CS-33084e

M.P.	DI			DP		RQI				
	'93e	'95e	'97e	'93e	'95e	'92e	'93e	'94e	'95e	'96e
9		1.96	8.86		0	71.8		21.6	28.8	28.8
9.5		2.82	11.44		0	76.5		25.8	32.4	33.2
10		4.26	12.78		0	73.2		25.8	31.4	31.4
10.5		2.7	12.78		0	77		26.2	32.2	32.6
11		3.38	13.4		0	74		22.2	29.2	30
11.5		3.8	9.68		0	69.2		25	30	32
12		3.18	7.32		0	69.2		21	29.6	30.8
12.5	N.A	6.94	10.7	N.A	0	74	N.A.	35	40	40
13		8.52	6.16		0	68.4		31.8	39.8	42.2
13.5		3.94	8.08		0	56.2		20	30.6	31.2
14		4.24	6.68		0	60.2		13.8	28.6	28
14.5		4.04	4.68		0	65.75		11.5	23.5	
15		5.4	18.32		0	69.8		13.6	24.4	24.4
15.5		6	19.26		0	71.6		15.6	26	26
16		5.92	19.18		0	68		18.8	26.4	28.8
16.5		12.38	30.92		0	69.2		17.4	25.8	27.2
17		7.58	20.7		0	66.25		18.5	30	27.25

DI, DP and RQI Data for Flexible Pavements (continued)

CS-33091

M.P.	DI			DP		RQI				
	'92n	'94n	'96s	'92n	'96s	'92n	'93s	'94s	'95s	'96n
2	10.775	2.0375	17.7	1.794944	4.5	65.6	71.2	70.8	65.5	50.6
2.5	4.3	5.72	13.42	1.658	5.144	36.2	37.6	38.6	41	44.2
3	7.24	9.424826	19.62	5.17	9.822	33.2	37.6	37.6	43.5	44.2
3.5	3.82	7.592	46.6	2.438	18.938	34.6	39	41.8	47.2	52.6
4	4.48	13.292	68.9	1.36	25.912	38	46.2	49.4	47	59.4
4.5	26.64	29.394	47.88	12.082	29.25	38.6	47.6	50.8	49.2	59
5	13.12	20.862	52.32	6.778	27.706	34.2	37.4	46.4	45.2	52.6
5.5	39.46	35.668	41.1	21.892	28.21	36.8	47.6	46	44.75	52.6
6	19.08	28.92689	48.8	8.756	28.778	46.2	49.4	52.4	57	63.6

CS-81013

M.P.	DI			DP		RQI				
	'92n	'94s	'96s	'94s	'96s	'92s	'93s	'94s	'95s	'96s
0	15.8	0	14.1	0	7.70809	44.4	48	50.8	51.6	54
0.5	8.2	0	3.78	0	1.15	42.8	46	46.8	49.4	50.4
1	11.32	0	8.36	0	4.292	48.8	49.4	51	53.4	50.6
1.5	18.72	0.2	11.42	0.21	6.134	50	50.4	51.2	52.8	53.4
2	16.44	0.52	10.38	0.21	4.206	38.6	42.8	43.6	48.2	49
2.5	8.32	0	20.2	0	11.306	38.4	42.4	42.2	45.2	47.4
3	6.82	0.4	14.18	0	6.972	35	38	38.4	42.4	41.8
3.5	5.12	0.7	10.22	0	4.942	41.6	50	49.2	50.8	52
4	3.56	1.64	8.74	0	4.914	37.4	43.2	39.6	43.6	47
4.5	5.82	2.1	13.94	0.386	7.868	50.2	53.4	55	52	53.2

DI, DP and RQI Data for Flexible Pavements (continued)

CS-35012

M.P.	DI			DP		RQI				
	'92s	'94n	'96n	'94n	'96n	'92n	'93s	'94n	'95s	'96n
7	8.675	7.4	3.92	1.204	1.638	44.2	43.6	58.8	49.5	59.8
7.5	7.7	15.26	22	4.896	7.582	50.4	49.4	56.2	55.6	58.4
8	3.22	9.26	13.7	3.256	5.45	47.2	50.8	40	54.8	51.2
8.5	14.72	21.1	123.98	5.398	7.332	55.2	55.2	56	59.4	60.8
9	8.9	12.58	16.82	5.206	8.78	42.2	42.4	44.6	49	54.4
9.5	3.88	5.94	17.8	1.548	4.274	39.8	38.4	34.8	44.4	46.4
10	4.86	9.46	21.58	1.512	4.204	50.4	46	48.6	52.6	56
10.5	6.42	10.3	34.54	1.574	4.442	46.4	42.8	46.6	50.8	55
11	3.16	13.76	34.6	2.66	2.972	42	43	37	52.6	48.6
11.5	6.88	10.98	28.26	2.526	6.882	41.6	45	47.8	50.4	57.8
12	12.92	11.86	45.7	5.798	11.67	47.6	53.4	50	51.4	53
12.5	15.28	8.88	31.52	3.286	7.454	50.4	50.6	48.8	49.8	53.4
13	15.9	5.82	29.56	1.276	2.686	50.2	51.4	45.6	43	46
13.5	13.78	11.24	55.5	4.49	12.272	43	45	53.2	54	62
14	12.08	6.86	34.76	3.498	7.47	44.8	49.2	48.4	55.4	55
14.5	10.58	10.12	34.08	4.424	10.094	50.4	55.6	45.2	60	50.6
15	10.08	24.34	54.22	8.862	15.78	43.8	49.4	59	57.2	72
15.5	14.52	18.22	88.98	9.386	13.458	50.8	57.2	51.2	57	62.2

DI, DP and RQI Data for Flexible Pavements (continued)

CS-47014n

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0	2.62	27.3	13.68333	0	1.742	60.25	40.5	37.5	45.5	44.75
0.5	1.233333	10	10.48	0	0.632	65.4	40.6	41	44.4	43.6
1	4	8.22	5.92	0	0	60.2	34.6	34.4	38.6	40
1.5	4.22	7.98	4.08	0	0	62.2	35.2	34.4	39.6	40.6
2	4	8.38	4.5	0	0	61.2	35	34	36.6	38.2
2.5	4	5.84	8.06	0	0	56.2	31.4	31.8	36.4	37.2
3	4	4.26	8.2	0	0	51.6	27.2	29.2	32.6	35.2
3.5	4	4.38	8.34	0	0	51.8	30.8	31.6	35	37.2
4	3.7	12.65	5.9	0	0.5125	58	34.25	40.25	39	40.75
4.5	3.42	6.2	8.4	0	0	51.4	31.2	31.8	38	39
5	4	6.16	8.56	0	0	47.4	27.4	30.4	34	36.4
5.5	4	7.56	7.56	0	0	53.4	27.8	28.8	35	36.8
6	4	7.82	8.32	0	0	65.6	29.8	32.4	37.6	40.2

DI, DP and RQI Data for Flexible Pavements (continued)

CS-47041

M.P.	DI			DP		RQI				
	'92e	'94e	'96e	'92e	'96e	'92e	'93e	'94w	'95e	'96w
13.5	25.16	51.3	77.92	5.186	41.302	56.2	57	62.8	53.6	55.2
14	19.9	32.76	62.52	5.66	33.4	46.4	45.8	46	52.8	54
14.5	18.66	23.66	42.6	5.08	19.034	56	53	61.6	64.8	61.2
15	13.54	27.36	49.98	3.348	25.89	62.8	55.6	64	59.8	67.2
15.5	29.02	30.12	53.08	7.114	32.242	60.8	59.4	67	63.8	64
16	3.34	8.58	10.5	0.96	1.57	50.2	56.4	55.6	47.8	44.2
16.5	20.66	23.06	35.74	2.426	13.898	60.8	52	52.8	68	67.8
17	19.34	49.18	95	4.386	53.96	75.2	73	71.25	76	81
17.5	14.66	38.52	67.46	1.964	35.31	63.2	52.6	75.5	54.6	73.6
18	10.72	23.16	64.94	0.526	27.45	67.8	57.2	66.8	62.6	75
18.5	18.86	34.48	57.44	4.41513	41.888	55.2	66.4	65.6	66	53.25
19	19.14	63.325	104.425	7.84	71.9975		59.75	64	61.8	66.6
19.5	35.3	54.44	80.54	5.806	44.394	58.6	69.2	58.6	61.6	62
20	44.34	51.98	89.4	8.154	47.97	65.6	59.8	62.6	64.2	68
20.5	17.94	27.62	44.26	4.392	19.078	65	74.8	68.8	61.25	74.4
21	62.08	84.52	102.94	8.362	41.456	56.8	55.4	58.8	58.2	71.2
21.5	28.1	47.6	72.46	10.554	34.538	62	60.6	66	68	66
22	29.86	47.44	79.7	9.572	36.188	59.4	56.6	57.4	55.2	64
22.5	22.14	58.58	100.56	6.386	61.038	48.4	47.6	54	47	60

DI, DP and RQI Data for Flexible Pavements (continued)

CS-53034n

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0	6.74	9.32	8.88	0	0	29.4	28.6	29.6	40.6	42.6
0.5	3.02	1.7	2.94	0.188	0	23.6	24.2	25.2	35.4	38
1	2.9	2.06	5.2	0	0	23.8	23.6	26	36.2	45
1.5	2.04	4.02	12.2	0	1.99	22.4	22.2	23.2	34	37.2
2	2.78	4.32	9.54	0	1.102	21	23.4	28	37.4	42.6
2.5	2.7	11.96	18.46	0	5.618	24.6	28.4	31.8	39.2	44.8
3	4.38	13.42	20.36	0	6.066	26.8	28	30.6	39.6	42.2
3.5	1.88	8.38	14.84	0	2.83	19.6	23	30.2	36.6	38
4	4.28	11.48	17.54	0.376	6.861163	20	23	25.75	35.8	39.8
4.5	2.78	11.84	18.26	0.188	8.464	19.8	25.6	29.4	35.6	44.2
5	1.58	5.4	22.74	0	2.39	17.6	20	28.2	33.2	40
5.5	2.12	3.9	14.86	0	1.294	17.2	22.2	29.2	35.4	40.2
6	1.3	5.14	11.36	0	1.53	14.2	14.8	19	29.8	34.4
6.5	2.34	4.62	17.46	0	1.278	22.2	25.6	29.4	37	41.4
7	3.06	7.72	21.88	0	3.81625	22.6	25.6	30.8	38.8	44.8
7.5	1.225	1.5	1.075	0	0	24.5	24	22.75	33	38.5
8	0.02	1.64	0.48	0	0	24.4	23.2	24.6	33	34.8
8.5	0.175	0.45	0.08	0	0	31.5	24.5	29.25	37.25	40
9	0.1	0.8	0.08	0	0	13.6	21.6	21.6	27	29.8
9.5	0	0.92	0.3	0	0	19.6	21.4	21	33.2	34.8
10	0	0.62	0.96	0	0	22.4	24.2	23.6	36	39.4
10.5	0.6		0.333333	0		30.33333	36.33333	34.66667	42.33333	51.33333

DI, DP and RQI Data for Flexible Pavements (continued)

CS-54014s

M.P.	DI			DP		RQI				
	'93s	'95s	'97s	'93s	'95s	'92s	'93s	'94s	'95s	'96n
0	8.24	12.16	11.875	2.061358	3.474175		47.4	49.2	54.6	59.4
0.5	17.62	17.36	14.56	3.92	5.308		46.4	46.2	47.4	56.4
1	16.06667	23.7	23.46	4.07	11.58881		44.75	51.75	52.66667	58.66667
1.5	14.6	23.24	19.42	1.063681	8.802		28.2	35	46	59.6
2	23.5	59.04	49.8	3.634	30.354		54.4	60.6	69.6	55.2
2.5	31.32	53.625	59.1	3.535196	18.53356		30.5	43	46.75	53.66667
3	34.76	53.88	48.56	0.762	16.268		20.6	30.2	38.8	46.6
3.5	27.52	44.66	49.14	1.674	15.56		26.6	30.8	43	49.2
4	15.02	30.06	31.18	0.188	8.826		20.2	27	39.8	54.4
4.5	16.24	33.8	30.58	0.934	11.34		29.5	26.75	37.25	54
5	14.26	21.12	15.525	1.12037	7.627833		16.6	30	38.25	50
5.5	19.86	35.44	18.54	1.346	14.68		14.4	28.6	37.2	48.2
6	22.7	31.78	27.08	0.396	10.666		26	30.4	41.4	47
6.5	10.98	14.44	13.52	0	2.826	N.A.	20.4	26.2	39.4	47.4
7	14.58	13.08	15.9	0.188	2.324		21.2	28.4	39.6	49
7.5	24.94	38.32	42.72	2.51	13.67		38.8	38.2	48.2	50.4
8	19.42	49.96	103.28	1.168	24.994		45.4	50.6	56.6	68.4
8.5	38.34	65.22	84.04	6.518	27.48		62.2	60.2	58.2	65.2
9	53.38	56.66	79.78	12.578	29.63		57.4	64.8	58	65.6
9.5	34.86	38.6	80.48	10.654	18.324		45	48.2	55.2	64
10	32.96	51.5	48.14	12.186	33.534		46.6	46.2	52.8	69
10.5	20.94	41.3	66.66	6.41	21.614		52	51.8	59.2	62.8
11	21.58	43.96	32.56	6.58	28.166		49.4	55.2	65.4	64.6
11.5	5.56	12.02	19.16	0.924	7.042		34.8	41	54.8	60.6
12	0.76	1.74	4	0	0.388		18.6	24.6	46.2	52.4
12.5	3.98	3.92	4.7	0	1.394		14.8	25.8	38.6	46.2
13	5.14	5.7	8.12	0	0.88		18.4	28.8	41.4	47
13.5	7.7	7.32	8.9	0	1.89		16	28	39.4	47
14	7.725	6.1	7.325	0	2.425833		12.75	21.5	35.25	48.33333
14.5	4.8	3.66	7.44	0	0.932		14.8	22.2	36.6	48.2
15	2.3	4.68	4.8	0	1.49		12.2	21.8	37.2	45.6
15.5	4.26	2.02	4.5	0	0.188		18	24.2	37.4	40.2

DI, DP and RQI Data for Flexible Pavements (continued)

CS-56032

M.P.	DI			DP		RQI				
	' 92n	' 94s	' 96n	' 92n	' 96n	' 92n	' 93n	' 94n	' 95s	' 96n
0	12.12	25.76	14.5	1.34	5.18	31.75	34.5	31.75	36.75	44
0.5	4.66	13.22	11.24	0	1.21	30.2	29.6	30.4	35.8	41.4
1	4.02	9.76	6.9	0	0	24.4	24.6	26.8	32.6	37.4
1.5	1.68	14.36	12.46	0	1.666	28.8	29.2	28.8	37.2	39.8
2	3.6	11.38	14.04	0	1.97	27	27.6	26.6	37.2	38.4
2.5	5.16	15.4	16.12	0	3.142	24.6	27.2	24.4	35.2	37.2
3	4.36	12.6	13.32	0	3.912	26.4	26	25.4	34	36
3.5	5.64	15.56	21.4	0	6.332	30.4	28.2	27.6	34.8	38.4
4	10.82	29.46	45.68	0	26.726	34.8	35.6	35.4	34.8	46.8
4.5	5.98	18.84	25.78	0	7.298	39.6	38.8	39.2	38.2	47.2
5	5.52	16.58	19.82	0.15	6.454	36.8	36	36.4	37.4	44.8
5.5	5.32	19.16	21.8	0	10.32	34.4	34.2	35.6	41.4	42.8
6	5.04	12.48	7.98	0	3.628	30.8	32.2	33.2	38.2	41.4
6.5	4.38	9.32	8.18	0	2.17	32.2	33.8	34	34.8	42.4
7	4.3	10.82	8.86	0	2.982	31.6	31.8	35	39.6	43.2
7.5	4.7	10.88	8.92	0	3.258	37.8	36	39	40.2	45.2
8	4	9.32	8	0	2.362	33.4	33.4	34.8	40	40.6
8.5	4	8.26	2.08	0	0.196	46.2	46	48.8	41.4	51.8

DI, DP and RQI Data for Flexible Pavements (continued)

CS-66021

M.P.	DI			DP			RQI				
	'92e	'93e	'95e	'92e	'93e	'95e	'92e	'93e	'94e	'95e	'96e
0	26.78	31.92	46.04	8.454	10.61	17.28	63.4	66.8	71	73.4	73.4
0.5	29.44	40.42	63	10.552	16.048	27.986	57.4	56.2	61.2	70.6	69
1	24.8	34.82	70.18	14.986	21.852	42.018	49.2	47	47.8	57.6	60.2
1.5	30.32	42.46	82.46	19.894	26.924	53.332	49.6	53.8	58.4	64.6	67
2	24.72	40.32	86.64	15.496	26.256	57.038	47	47.4	54.4	58.6	62.2
2.5	26.16	33.02	69.78	19.482	24.15	47.436	45.2	52.2	56.2	57.4	60.8
3	53.06	68.64	110.16		52.104	84.69	33.8	52.6	57.8	59.4	62.6
3.5	40.55	41.925	75.925	22.71103	24.47375	50.56806	43.75	55.25	54.75	63.25	68
4	42.225	42.1	86.1	29.52877	28.56034	65.2535	43.25	57.5	58.25	60.2	71
4.5	75.54	88.02	159.72	52.7	56.852	116.364	59	60.4	63.6	60	72.5
5	96.64	96.06	167.46	74.436	70.776	125.302	64.6	58.6	63.6	65.4	69
5.5	43.02	52.66	116.58	27.864	34.812	90.862	65.8	54.4	65	64.4	71.2
6	61.36	69.68	140.04	38.168	43.878	105.392	64.2	49.8	59.6	61.8	68.8
6.5	46.74	43.7	91.7	29.862	28.374	72.338	53.8	63.4	72.4	70.2	78.6
7	78.2	74.16	153.34	53.016	49	123.814	47	60.8	69.6	68.8	72
7.5	77.2	85.04	164.6	48.312	52.182	112.818	54.4	59.6	66	69.8	71.8
8	64.4	66.3	123.08	42.99434	41.25152	97.13863	66	65	73.4	74.2	78.6

DI, DP and RQI Data for Flexible Pavements (continued)

CS-67016n

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0	3.56	12.4	29.26667	0.386	0.836	17.75	18.5	26.5	37.5	34.5
0.5	12.16	12.14	15.76	0	0.654	14.2	18.2	25	32.4	31.4
1	9.2	12.3	16.56	0	0.196	12.4	14	21.2	31.8	30.6
1.5	12.52	12.72	13.9	0	0.307983	17.4	18	22.8	33.6	34.8
2	17.125	16.475	18.725	1	1.755	25.75	26.25	28.5	40.25	39.75
2.5	15.525	14.54	21.1	0.123737	0.907347	19.4	21.6	23.6	38.4	38
3	11.58	12.175	18.15	0	2.2475	31.25	23.5	30.75	41.25	35.25
3.5	12.92	14.42	20.4	0	0.5	21.8	22.4	33.4	44.6	44
4	11.775	12.54	24.98	0	1.751322	23.5	23.25	28	39.75	37.66667
4.5	8.7	14.75	27.4	0	2.977143	22	28.25	31.25	38.66667	45
5	18.66667	18	30.93333	0.877661	3.480852	25	24.66667	39.66667	45.66667	59

CS-54021

M.P.	DI			DP		RQI				
	'92e	'94e	'96w	'94e	'96w	'92e	'93e	'94w	'95e	'96w
2	10.98	6.925	420.8	0.671667	9.825808		56.25	56	64.33333	58.33333
2.5	10.08	32.92	163.46	7.714	4.35	N.A.	42.8	40.6	46.6	52
3	6.4	31.48	46.76	8.21	6.29		40	42.4	44.2	50.25

DI, DP and RQI Data for Flexible Pavements (continued)

CS-61074n

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0	8.88	35.16	202.96	1.092	12.132		37	48.6	45.8	57
0.5	30.92	71.88	556.08	2.918	27.882		40.4	51.6	50.6	52.6
1	21.98	63.2	490.86	6.456	37.71		39.8	40.8	43.2	48.4
1.5	14.88	56.32	397.52	1.104	24.536	N.A.	44.6	44	41.4	49.6
2	13.44	54.32	283.22	0.892	29.094		39.6	42.6	42.6	47.2
2.5	20.06	69.94	362.38	2.778	43.802		44.4	52	51.2	52

CS-70016n

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0	10.86	73.55	191.96	2.258853	21.55585		41.66667	45.33333	71	47
0.5	14.86	74.78	53.86	3.53	36.126		39.2	39.8	72.2	45.8
1	10.14	28.72	27.98	1.088	9.494	N.A.	33.8	34.8	67.2	41.4
1.5	24.82	51.52	41.14	5.26	24.758		37	40.8	74	45.8
2	34.44	60.36	61.8	13.088	33.812		41.2	41.6	80.4	50.4
2.5	19.02	48.15	53.6	2.65	20.91		51.4	44.4	79.2	53.6

DI, DP and RQI Data for Flexible Pavements (continued)

CS-61074

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0	8.88	35.16	202.96	1.092	12.132		37	48.6	45.8	57
0.5	30.92	71.88	556.08	2.918	27.882		40.4	51.6	50.6	52.6
1	21.98	63.2	490.86	6.456	37.71	N.A.	39.8	40.8	43.2	48.4
1.5	14.88	56.32	397.52	1.104	24.536		44.6	44	41.4	49.6
2	13.44	54.32	283.22	0.892	29.094		39.6	42.6	42.6	47.2
2.5	20.06	69.94	362.38	2.778	43.802		44.4	52	51.2	52

CS-72014

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0	81.76	84.06	204.36	46.208	27.33	62.4	63.4	69	69.4	75
0.5	68.9	65.22	115.82	39.972	25.992	49.2	51.8	56	54	60.2
1	62.76	51.44	235.44	31.38	11.97	39	50.2	63.6	49.6	59.6
1.5	54.56	51.36	211.46	24.608	13.052	46	57.4	58.6	53.2	54
2	40.92	36.66	90.48	17.014	4.304	44	55	55.4	55.4	58.2
2.5	37.52	32.34	76.02	11.114	3.862	43.2	52	51.2	49	52.6
3	40.7	38.12	142.58	11.082	4.498	43.6	49.6	47.6	54.6	52.2
3.5	23.66	23.56	78.22	4.426	1.724	44.2	40.8	43	49.6	46.6
4	24.5	23.94	43.42	5.722	2.102	46.2	48.2	51	55.6	50
4.5	42.48	35.2	151.1	14.296	5.656	45.2	42.6	49.6	52.6	51.2
5	32.05	30.25	214.975	7.9575	3.569752	57.75	56.4	57.25	58.4	56.66667
5.5	23.56	26.46	147.52	2.504	2.04	48.2	50.8	55.6	58.4	55.4
6	28.94	30.72	60.7	7.05	3.94	47.6	50.8	55.8	60.2	56.4
6.5	39.36	49.2	166.52	15.606	14.934	51.6	52	59.6	61.8	57.6
7	57.96	37.92	78.14	34.738	7.678	47.2	46.2	52.4	62.4	57.6
7.5	30.96	29.44	53.42	12.108	3.51	39.4	39.4	43.6	50.8	46.6
8	14.94	27.64	52.3	4.658	4.596	38.8	40.4	37.2	47.2	47.6
8.5	29.06	31.3	75.8	12.554	4.794	55.6	51.6	56.2	59.2	59.4

DI, DP and RQI Data for Flexible Pavements (continued)

CS-80012n

M.P.	DI			DP		RQI				
	'93n	'95n	'97n	'93n	'95n	'92n	'93n	'94n	'95n	'96n
0	73.8	146.46	5.38	13.006	77.898	59.2	68	66.4		29.2
0.5	62.1	123.86	2.52	13.512	82.244	62.8	63.2	63.8	N.A.	34.8
1	56.2	111	2.88	12.602	63.18	59	64.6	56.2		31.8
1.5	3.16	8.44	27.44	0	0	51.6	26.6	27	33.5	35.2
2	4.14	8.46	37.56	0	0	60	29.2	30.2	35.6	37.2
2.5	4.04	10.8	56.06	0	0.396	59.6	26	26.2	34.4	38
3	4	8.14	38.06	0	0	63.8	26.4	25.8	34	37.8
3.5	3.96	8.3	22.72	0	0	50.6	25.4	25.4	33.6	33.2
4	27.08	63.84	11.8	4.668	38.434	43.4	53.2	51	61.4	34
4.5	44.825	115.5	7.075	3.832796	73.18603	52.75	61	55.25	71.5	33.66667
5	48.68	133.48	7.92	3.844	87.108	61.2	66.6	56	80.6	36.4
5.5	26.24	75.3	8.34	7.572	39.318	61.2	66.6	61.4	72.4	36.2
6	21.82	54.46	4.02	6.858	25.218	61.2	57	51.4	63.2	29.2
6.5	43	55.14	3.24	10.856	26.418	68.8	69.2	64.2	64.4	30.8
7	27.92	59.2	0.38	5.712	29.778	53.8	57	47.2	58.2	24.8
7.5	30.175	82.15	1.275	10.36203	43.30713	59	59.5	55.5	58	32
8	16.54	41.26	6.82	4.25	21.178	43.6	41.2	45	55.6	30
8.5	36.625	68.8	1.13	16.06556	46.13	59.25	57.5	53.25	61	38.25

DI, DP and RQI Data for Flexible Pavements (continued)

CS-80042

M.P.	DI			DP		RQI				
	'92	'94w	'96w	'94w	'96w	'92w	'93e	'94e	'95e	'96e
0		124.68	2.18	24.838	0.304	66.8	64	64	72.4	29.2
0.5		46.2	2.62	10.672	0	50.4	43	46.4	57.6	22
1		74.28	0.56	12.816	0	48.8	43.4	46.4	58.6	25.8
1.5		202.14	0.28	33.098	0	52.8	63.6	70.2	75.8	19
2		196.94	0.3	19.094	0	49.4	63.8	67.6	73	21.6
2.5		187.64	0.46	57.166	0	63	61.6	63.4	73	19.8
3		168.6	0.44	32.774	0	64	68.2	65.6	64.25	23.8
3.5		98.96	0.3	23.912	0	44.6	56	57.4	58	24.6
4		170.24	0.68	40.988	0	44.6	59.4	61.8	60.6	24
4.5	N.A.	102.38	0.54	52.276	0	47	54.8	63	57.2	23.2
5		104.38	1.08	47.524	0	47	62.6	58.6	65	21.4
5.5		52.54	0.36	17.564	0	45.8	61.4	58.6	74.2	19.8
6		43.58	0.96	9.78	0	49.8	47.6	52.2	54	21.2
6.5		0	0.08	0	0	67.6	74.4	71.6	29.6	27.8
7		0	0.1	0	0	59.2	70.2	81.4	23.8	23.8
7.5		0	0.44	0	0	53.75	65.6	70.4	23.4	25.6
8		2.1	0.32	0	0	58.2	71.75	85.5	23.25	26
8.5		0	0.2	0	0	53.2	71.8	73.2	23.4	24.6
9		0	0.7	0	0.338	50.4	59.6	56	29	31.2
9.5		0	2.6	0	0.996	55.4	55	56.6	25.4	27
10		0	1.9	0	0.188	52	59.8	57.2	35.5	34.75

CS-08081

M.P.	DI			DP		RQI				
	'92	'94w	'96e	'94w	'96e	'92	'93w	'94w	'95w	'96w
0		211.18	323.44	39.59457	25.342	49.4	58.2	67	66.2	67
0.5		158.38	442.16	29.88	18.46	50.6	52.8	56.4	56.8	58
1	N.A.	197.54	332.04	23.16	32.364	50.4	60.6	58.4	62.8	68
1.5		173.56	681.34	18.924	11.632	57.8	48.8	43.8	53.2	55.6
2		142.64	209.3	46.432	43.386	39.8	50.2	50.2	55.6	55

Proportions of Distress Types in the Distress Index for Rigid Pavements from Data Set #1

0<DL<10

Distress Types	DP		Proportion of DP	
	Low-RQI	High-RQI	Low-RQI	High-RQI
TC-N	18	81.5	0.25	0.25
TC-A	17.69	64	0.25	0.19
TJ	12.16	101.87	0.17	0.31
LC	2.1	1.1	0.03	0.00
LJ	13.12	2.4	0.18	0.01
DL	4	0	0.06	0.00
Patch	4	78	0.06	0.24
Total	71.07	328.87	1.00	1.00

10<DL<20

Distress Types	DP		Proportion of DP	
	Low-RQI	High-RQI	Low-RQI	High-RQI
TC-N	564	69.5	0.52	0.07
TC-A	176.41	386.47	0.16	0.38
TJ	121	201.02	0.11	0.20
LC	0.64	3.94	0.00	0.00
LJ	167	15.2	0.15	0.01
DL	47	76	0.04	0.07
Patch	10	267	0.01	0.26
Total	1086.05	1019.13	1.00	1.00

20<DL<30

Distress Types	DP		Proportion of DP	
	Low-RQI	High-RQI	Low-RQI	High-RQI
TC-N	122	8	0.24	0.02
TC-A	141.47	252.75	0.28	0.53
TJ	185.49	115.46	0.37	0.24
LC	0.36	4.84	0.00	0.01
LJ	56	47.38	0.11	0.10
DL	0	33	0.00	0.07
Patch	1.6	18	0.00	0.04
Total	506.92	479.43	1.00	1.00

30<DL<40

Distress Types	DP		Proportion of DP	
	Low-RQI	High-RQI	Low-RQI	High-RQI
TC-N	192	24.5	0.30	0.04
TC-A	301.78	281	0.47	0.45
TJ	65.93	93.64	0.10	0.15
LC	0	4.6	0.00	0.01
LJ	82.32	7.6	0.13	0.01
DL	0	116	0.00	0.19
Patch	3	98	0.00	0.16
Total	645.03	625.34	1.00	1.00

Proportions of Distress Types in the Distress Index for Composite Pavements from Data Set #1

10<DI<20

Distress Types	DP		Proportion of DP	
	Low-RQI	High-RQI	Low-RQI	High-RQI
TT	57.1	25.8	0.10	0.05
TC-N	208	183.5	0.35	0.32
TC-A	201.7	172	0.34	0.30
LC-c-N	39.2	64.9	0.07	0.11
LC-c-A	54.1	36.8	0.09	0.07
LC-e-N	1.3	13	0.00	0.02
LC-e-A	2.1	28.8	0.00	0.05
LC-w-N	4	20.2	0.01	0.04
LC-w-A	18.8	20.4	0.03	0.04
sum	586.3	565.4	1.00	1.00

20<DI<30

Distress Types	DP		Proportion of DP	
	Low-RQI	High-RQI	Low-RQI	High-RQI
TT	23.9	60	0.04	0.08
TC-N	221	58.5	0.38	0.08
TC-A	164.5	450.3	0.29	0.59
LC-c-N	28.4	15.3	0.05	0.02
LC-c-A	93.9	82.6	0.16	0.11
LC-e-N	1.9	17.4	0.00	0.02
LC-e-A	0.5	38.7	0.00	0.05
LC-w-N	17.6	7.9	0.03	0.01
LC-w-A	23.7	34.7	0.04	0.05
sum	575.4	765.4	1.00	1.00

30<DI<40

Distress Types	DP		Proportion of DP	
	Low-RQI	High-RQI	Low-RQI	High-RQI
TT	15.7	64.9	0.02	0.05
TC-N	267	18.5	0.28	0.01
TC-A	403.2	838.3	0.43	0.65
LC-c-N	9.9	25.7	0.01	0.02
LC-c-A	207.4	172	0.22	0.13
LC-e-N	0.3	30.6	0.00	0.02
LC-e-A	8.3	104.6	0.01	0.08
LC-w-N	7.4	5.2	0.01	0.00
LC-w-A	22.1	21.7	0.02	0.02
sum	941.3	1281.5	1.00	1.00

Proportions of Distress Types in the Distress Index for Composite Pavements from Data Set #1 (Continued)

40<DI<50

Distress Types	DP		Proportion of DP	
	Low-RQI	High-RQI	Low-RQI	High-RQI
TT	52.3	30.1	0.06	0.03
TC-N	127.5	66	0.15	0.07
TC-A	501.6	590.7	0.59	0.66
LC-c-N	10.6	15.7	0.01	0.02
LC-c-A	113	98.5	0.13	0.11
LC-e-N	0.1	12.2	0.00	0.01
LC-e-A	12.2	40.5	0.01	0.05
LC-w-N	4.1	8.4	0.00	0.01
LC-w-A	29.8	37.7	0.04	0.04
sum	851.2	899.8	1.00	1.00

Proportions of Distress Types in the Distress Index for Flexible Pavements from Data Set #1

10<DI<20

Distress Types	DP		Proportion of DP	
	Low-RQI	High-RQI	Low-RQI	High-RQI
TT	99.4	86	0.12	0.16
TC-N	110	104.5	0.14	0.19
TC-A	225.9	130.2	0.28	0.24
LC-c-N	120.9	22.2	0.15	0.04
LC-c-A	193.9	118.8	0.24	0.22
LC-e-N	0.4	6.9	0.00	0.01
LC-e-A	14.7	52.4	0.02	0.10
LC-w-N	9.5	1.8	0.01	0.00
LC-w-A	34.9	24.3	0.04	0.04
sum	809.6	547.1	1.00	1.00

20<DI<30

Distress Types	DP		Proportion of DP	
	Low-RQI	High-RQI	Low-RQI	High-RQI
TT	77.3	63.6	0.14	0.13
TC-N	42	53.5	0.08	0.11
TC-A	139	207.4	0.26	0.41
LC-c-N	8.5	19.7	0.02	0.04
LC-c-A	190.5	89	0.36	0.18
LC-e-N	1	6.6	0.00	0.01
LC-e-A	15.5	48.2	0.03	0.10
LC-w-N	2.2	3.1	0.00	0.01
LC-w-A	58.1	15.3	0.11	0.03
sum	534.1	506.4	1.00	1.00

30<DI<40

Distress Types	DP		Proportion of DP	
	Low-RQI	High-RQI	Low-RQI	High-RQI
TT	121.3	8.7	0.10	0.03
TC-N	128.5	85.5	0.11	0.25
TC-A	269.7	164.6	0.23	0.47
LC-c-N	21.1	11.2	0.02	0.03
LC-c-A	409.4	57.7	0.35	0.17
LC-e-N	3.7	0.2	0.00	0.00
LC-e-A	88.6	13.4	0.08	0.04
LC-w-N	3.9	0.2	0.00	0.00
LC-w-A	126	6.1	0.11	0.02
sum	1172.2	347.6	1.00	1.00

Proportions of Distress Types in the Distress Index for Flexible Pavements from Data Set #1 (Continued)

40<DI<50

Distress Types	DP		Proportion of DP	
	Low-RQI	High-RQI	Low-RQI	High-RQI
TT	149	49.9	0.12	0.08
TC-N	187.5	57.5	0.16	0.10
TC-A	295.1	324.6	0.24	0.55
LC-c-N	22.5	12.9	0.02	0.02
LC-c-A	257.7	75.9	0.21	0.13
LC-e-N	6.6	1.7	0.01	0.00
LC-e-A	92.6	31.5	0.08	0.05
LC-w-N	6	1.3	0.00	0.00
LC-w-A	189.7	33.3	0.16	0.06
sum	1206.7	588.6	1.00	1.00

50<DI<60

Distress Types	DP		Proportion of DP	
	Low-RQI	High-RQI	Low-RQI	High-RQI
TT	65	75.7	0.14	0.07
TC-N	95.5	31.5	0.20	0.03
TC-A	114.7	648.5	0.24	0.59
LC-c-N	5	13.3	0.01	0.01
LC-c-A	79.5	159.7	0.17	0.15
LC-e-N	0.1	0.4	0.00	0.00
LC-e-A	6.1	135.6	0.01	0.12
LC-w-N	1.6	1.2	0.00	0.00
LC-w-A	113.4	33	0.24	0.03
sum	480.9	1098.9	1.00	1.00

Proportions of Distress Types in the Distress Index for Rigid Pavements from Data Set #2 and 3

0<DI<10

Distress Types	DP		Proportion of DP	
	Low-RQI	High-RQI	Low-RQI	High-RQI
TC-N	92.5	128	0.37	0.25
TC-A	40	201.99	0.16	0.39
TJ	104.86	110	0.42	0.21
LC	0.6	1.12	0.00	0.00
LJ	4.64	12.56	0.02	0.02
DL	0	13	0.00	0.03
Patch	5	53	0.02	0.10
Total	247.6	519.67	1.00	1.00

10<DI<20

Distress Types	DP		Proportion of DP	
	Low-RQI	High-RQI	Low-RQI	High-RQI
TC-N	252.5	117.5	0.30	0.12
TC-A	167.5	550.5	0.20	0.54
TJ	369.4	172.15	0.44	0.17
LC	0.16	0	0.00	0.00
LJ	40.88	69.12	0.05	0.07
DL	2	1	0.00	0.00
Patch	13	105	0.02	0.10
Total	845.44	1015.27	1.00	1.00

20<DI<30

Distress Types	DP		Proportion of DP	
	Low-RQI	High-RQI	Low-RQI	High-RQI
TC-N	232.5	32.0	0.27	0.04
TC-A	383.76	408.7	0.45	0.53
TJ	165.16	131.3	0.19	0.17
LC	1.24	0.0	0.00	0.00
LJ	69.36	55.5	0.08	0.07
DL	2	0.0	0.00	0.00
Patch	4	141.0	0.00	0.18
Total	858.02	768.5	1.00	1.00

30<DI<40

Distress Types	DP		Proportion of DP	
	Low-RQI	High-RQI	Low-RQI	High-RQI
TC-N	63	51.0	0.10	0.06
TC-A	436.5	225.8	0.68	0.25
TJ	19.1	178.1	0.03	0.19
LC	0	6.6	0.00	0.01
LJ	46.7	107.3	0.07	0.12
DL	64	0.0	0.10	0.00
Patch	15	347.0	0.02	0.38
Total	644.3	915.8	1.00	1.00

Proportions of Distress Types in the Distress Index for Composite Pavements from Data Set #2 and 3

10<DI<20

Distress Types	DP		Proportion of DP	
	Low-RQI	High-RQI	Low-RQI	High-RQI
TT	17.5	24.9	0.03	0.03
TC-N	104.5	142	0.15	0.15
TC-A	268.68	596.55	0.38	0.62
LC-c-N	96.06	28.9	0.14	0.03
LC-c-A	109.84	75.8	0.16	0.08
LC-e-N	21.24	14.28	0.03	0.01
LC-e-A	63.12	42.56	0.09	0.04
LC-w-N	1.8	8.6	0.00	0.01
LC-w-A	16.72	29.5	0.02	0.03
Total	699.46	963.09	1.00	1.00

20<DI<30

Distress Types	DP		Proportion of DP	
	Low-RQI	High-RQI	Low-RQI	High-RQI
TT	12.1	9.5	0.03	0.01
TC-N	60.5	192.75	0.14	0.17
TC-A	183.85	707.72	0.42	0.61
LC-c-N	28.74	18.6	0.07	0.02
LC-c-A	84.24	157.76	0.19	0.14
LC-e-N	10.72	2.24	0.02	0.00
LC-e-A	28.24	54.7	0.07	0.05
LC-w-N	5.63	3.44	0.01	0.00
LC-w-A	19.68	16.4	0.05	0.01
Total	433.7	1163.11	1.00	1.00

30<DI<40

Distress Types	DP		Proportion of DP	
	Low-RQI	High-RQI	Low-RQI	High-RQI
TT	44	5.8	0.05	0.01
TC-N	87.5	126.5	0.10	0.14
TC-A	461.37	497.1	0.54	0.55
LC-c-N	33.6	7.75	0.04	0.01
LC-c-A	120.7	104.08	0.14	0.12
LC-e-N	16.1	3.8	0.02	0.00
LC-e-A	50.4	98.48	0.06	0.11
LC-w-N	1.8	8.65	0.00	0.01
LC-w-A	33.92	50.1	0.04	0.06
Total	849.39	902.26	1.00	1.00

Proportions of Distress Types in the Distress Index for Composite Pavements from Data Set #2 and 3 (Continued)

40<DI<50

Distress Types	DP		Proportion of DP	
	Low-RQI	High-RQI	Low-RQI	High-RQI
TT	51.9	17.4	0.03	0.02
TC-N	104	36.5	0.05	0.04
TC-A	1221.9	608.45	0.62	0.65
LC-c-N	19.4	7.96	0.01	0.01
LC-c-A	257.2	78.8	0.13	0.08
LC-e-N	1.96	7.56	0.00	0.01
LC-e-A	169.1	37.7	0.09	0.04
LC-w-N	7.75	10.56	0.00	0.01
LC-w-A	123.4	132.6	0.06	0.14
Total	1956.61	937.53	1.00	1.00

Proportions of Distress Types in the Distress Index for Flexible Pavements from Data Set #2 and 3

10<DI<20

Distress Types	DP		Proportion of DP	
	Low-RQI	High-RQI	Low-RQI	High-RQI
TT	7.7	85.8	0.01	0.10
TC-N	6	141.75	0.01	0.16
TC-A	18.37	307.74	0.02	0.35
LC-c-N	1.6	35.1	0.00	0.04
LC-c-A	322.1	121.2	0.39	0.14
LC-e-N	15.7	7.46	0.02	0.01
LC-e-A	324.3	60.64	0.40	0.07
LC-w-N	2.1	4.28	0.00	0.00
LC-w-A	120.48	114.08	0.15	0.13
Total	818.35	878.05	1.00	1.00

20<DI<30

Distress Types	DP		Proportion of DP	
	Low-RQI	High-RQI	Low-RQI	High-RQI
TT	149.4	59	0.13	0.04
TC-N	106.25	159	0.09	0.11
TC-A	358.16	311.4	0.30	0.22
LC-c-N	6.16	16.8	0.01	0.01
LC-c-A	112.64	338.08	0.10	0.24
LC-e-N	7.24	0.88	0.01	0.00
LC-e-A	125.28	171.92	0.11	0.12
LC-w-N	3.14	2.98	0.00	0.00
LC-w-A	317	339.9	0.27	0.24
Total	1185.27	1399.96	1.00	1.00

30<DI<40

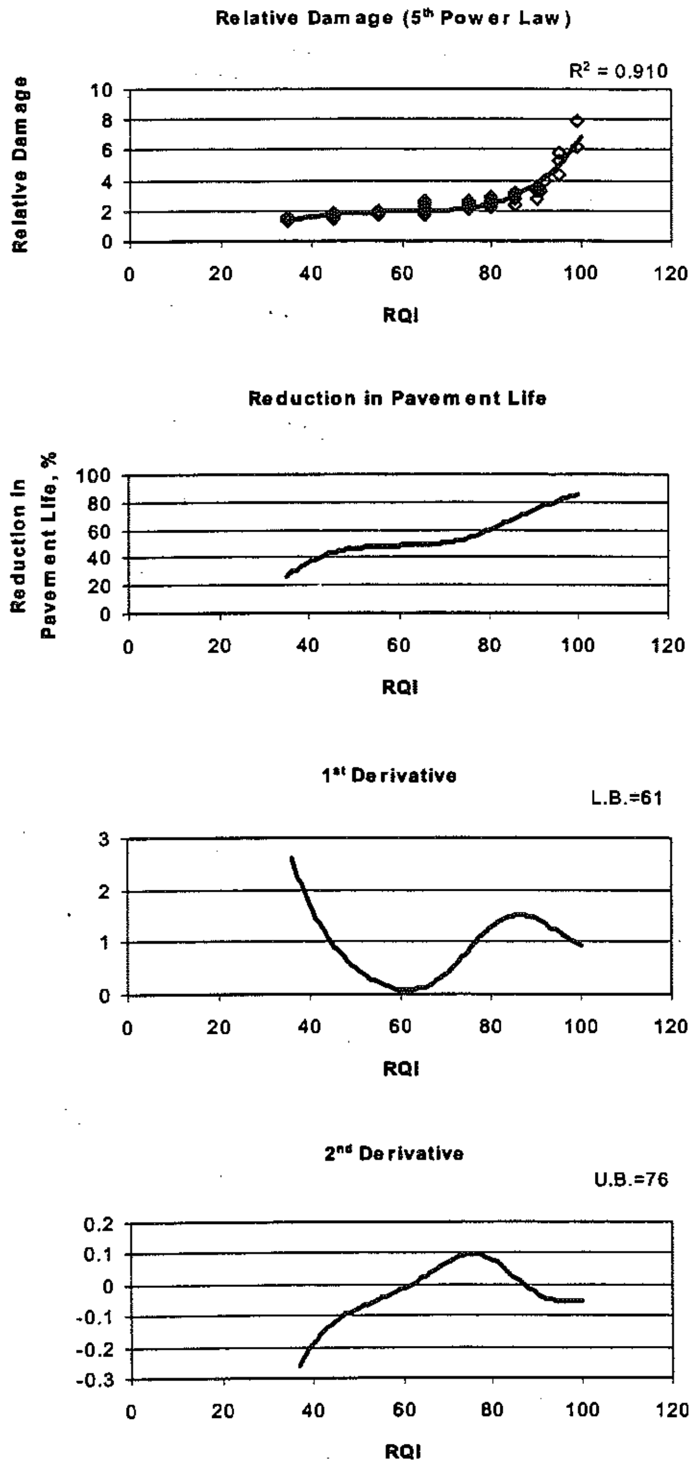
Distress Types	DP		Proportion of DP	
	Low-RQI	High-RQI	Low-RQI	High-RQI
TT	151.26	75.7	0.08	0.04
TC-N	134.5	150	0.07	0.07
TC-A	787.34	665.12	0.41	0.32
LC-c-N	4.86	14.64	0.00	0.01
LC-c-A	256.88	389.52	0.13	0.19
LC-e-N	6	2.32	0.00	0.00
LC-e-A	114	164	0.06	0.08
LC-w-N	3	4.96	0.00	0.00
LC-w-A	481.84	619.12	0.25	0.30
Total	1939.68	2085.38	1.00	1.00

Proportions of Distress Types in the Distress Index for Flexible Pavements from Data Set #2 and 3 (Continued)

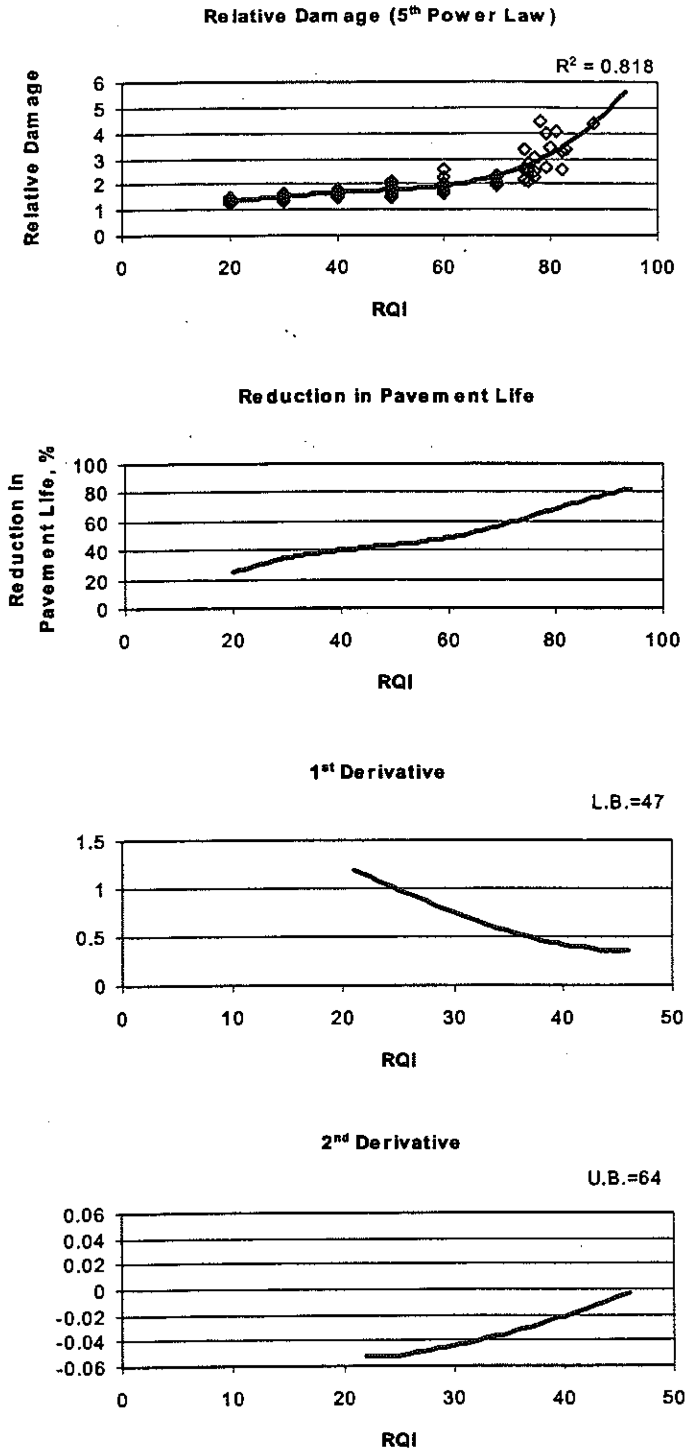
40<DI<50

Distress Types	DP		Proportion of DP	
	Low-RQI	High-RQI	Low-RQI	High-RQI
TT	144.8	60.5	0.07	0.03
TC-N	147.5	8.2	0.07	0.00
TC-A	1122.12	254.24	0.53	0.14
LC-c-N	26.08	0.52	0.01	0.00
LC-c-A	263.2	159.92	0.12	0.09
LC-e-N	0.58	3.16	0.00	0.00
LC-e-A	90.8	712.64	0.04	0.38
LC-w-N	9.37	95	0.00	0.05
LC-w-A	325.12	575.27	0.15	0.31
Total	2129.57	1869.45	1.00	1.00

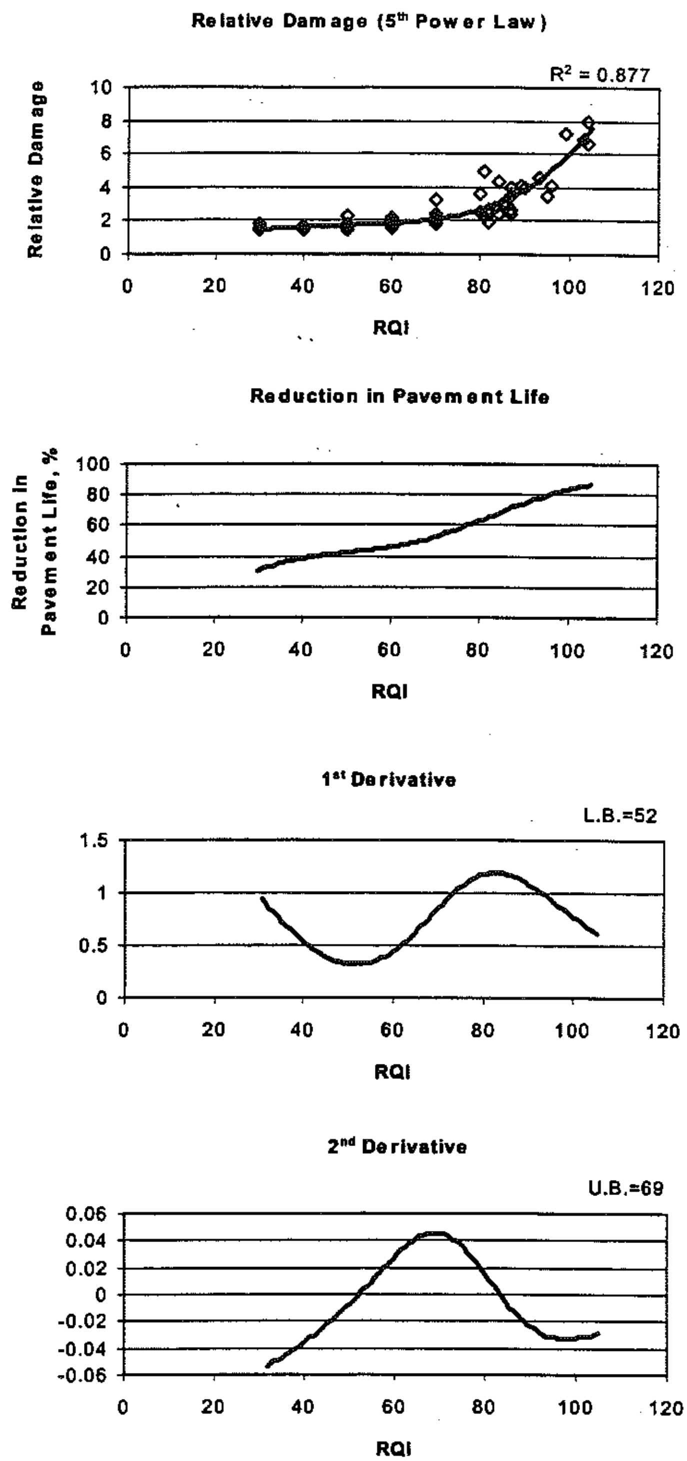
APPENDIX E
DL, Damage and DLI



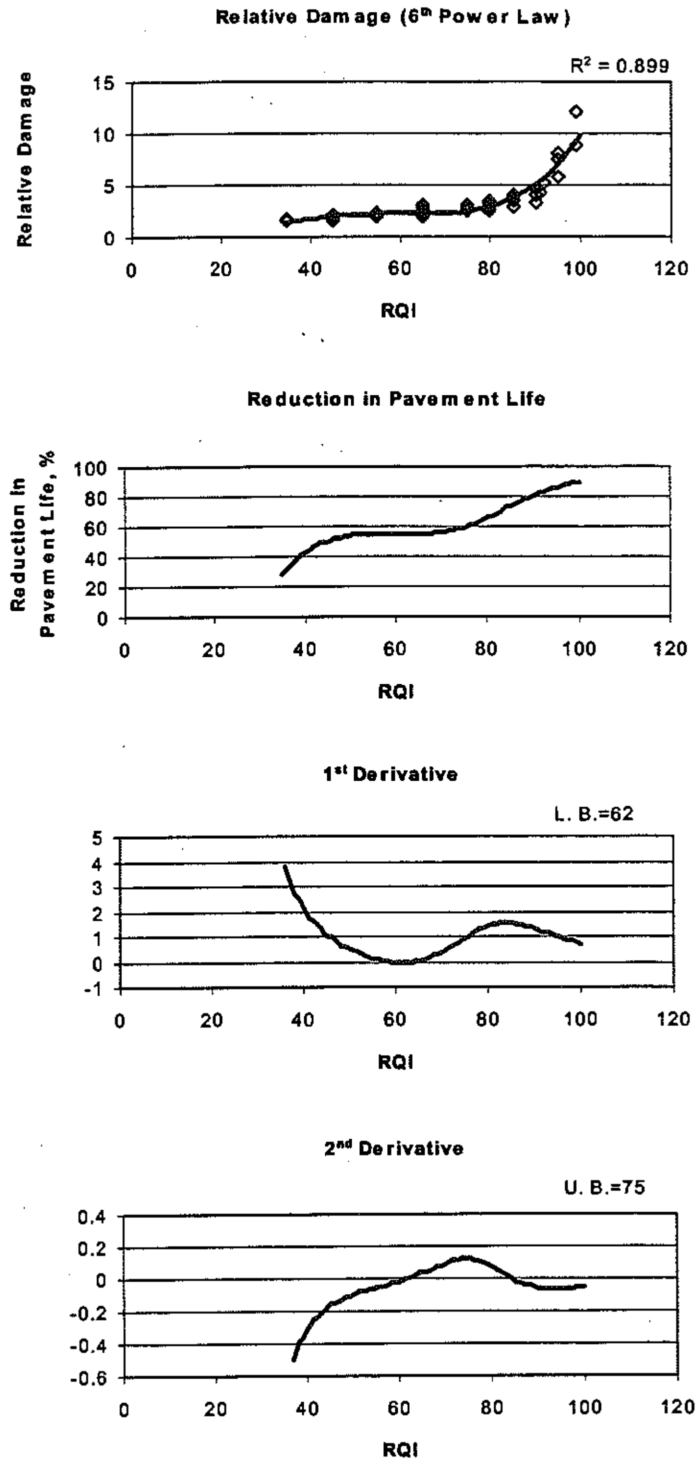
Relative Damage using 5th Power Law and Reduction in Pavement Life vs. RQI for Rigid Pavements



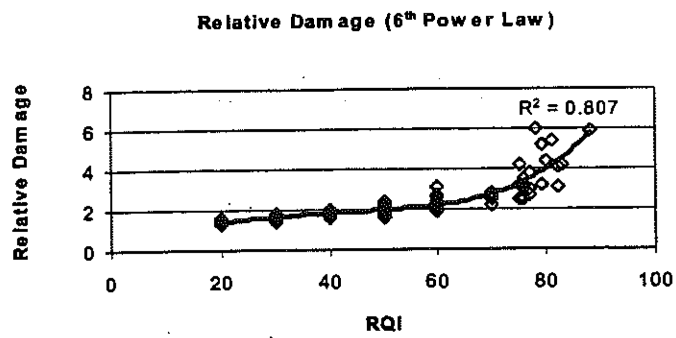
Relative Damage using 5th Power Law and Reduction in Pavement Life vs. RQI for Flexible Pavements

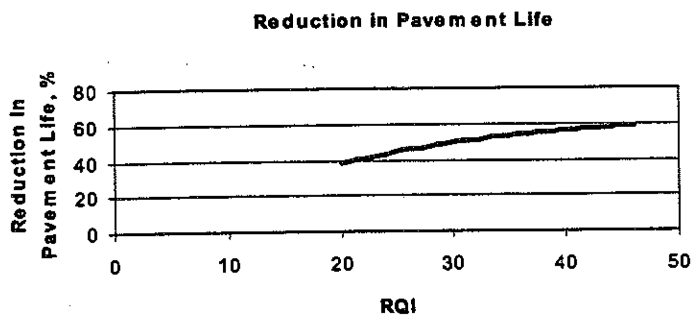


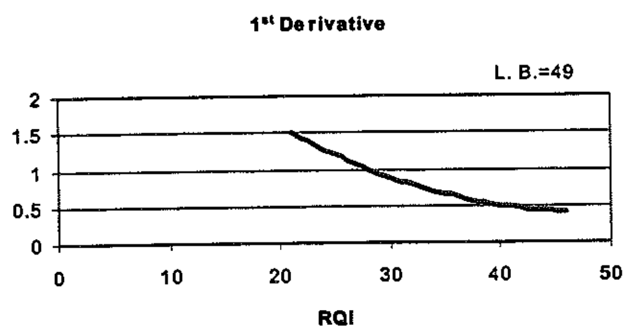
Relative Damage using 5th Power Law and Reduction in Pavement Life vs. RQI for Composite Pavements

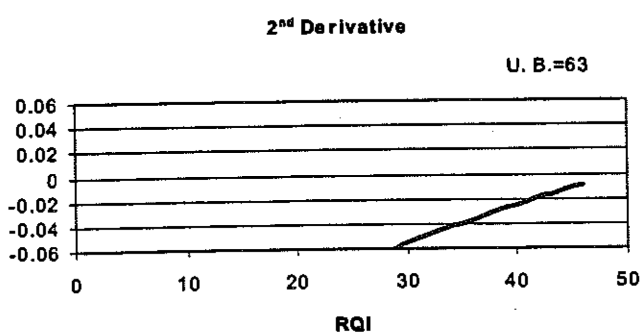


Relative Damage using 6th Power Law and Reduction in Pavement Life vs. RQI for Rigid Pavements

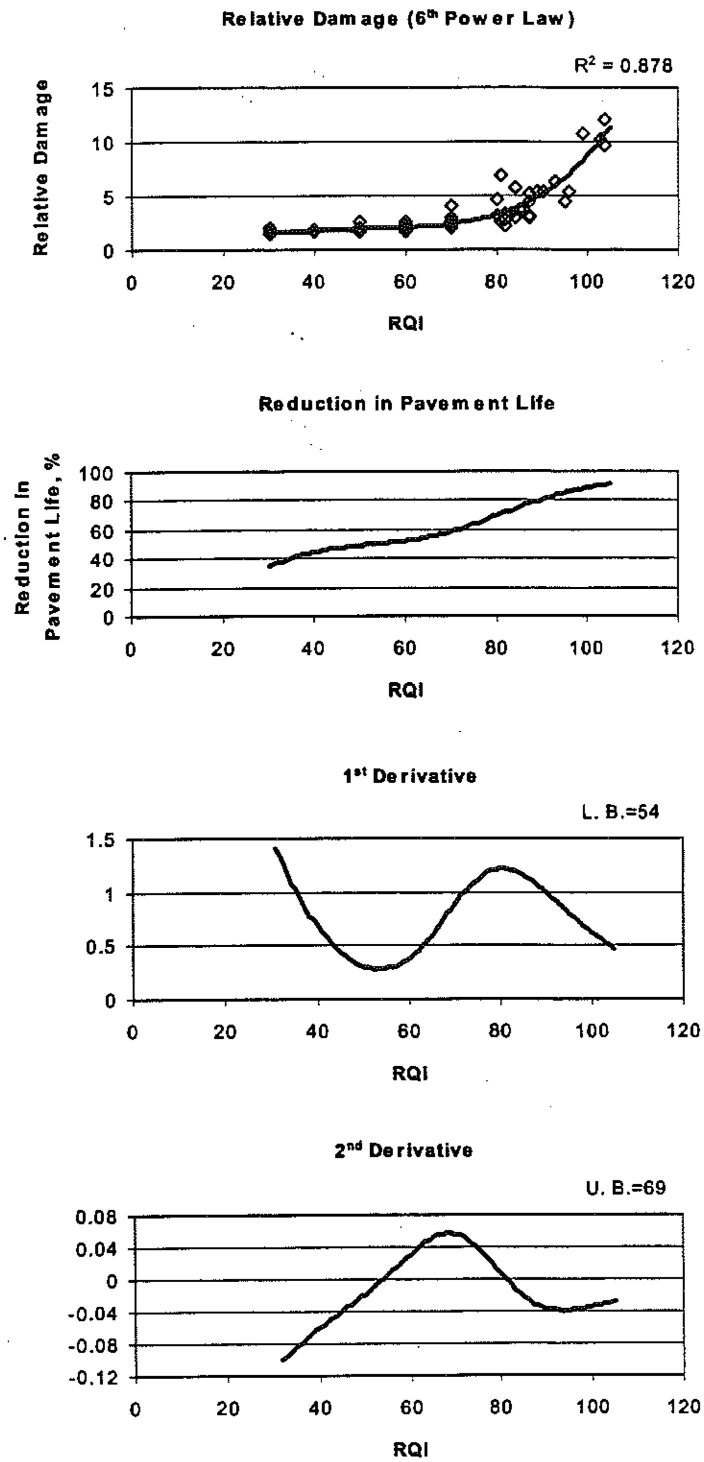








Relative Damage using 6th Power Law and Reduction in Pavement Life vs. RQI for Flexible Pavements



Relative Damage using 6th Power Law and Reduction in Pavement Life vs. RQI for Composite Pavements

RQI, DLC, 95th Percentile DL and DLI for Rigid Pavement Sections

RQI	Route No.	CS	M.P.	Year	95%tile DL	DLC	DLI
35	I-69	23063	0.1-0.2	94	9112	4.18	0.13
35	I-69	23063	1.3-1.4	94	9043	3.77	0.07
35	I-69	23063	1.4-1.5	94	9152	4.34	0.10
35	I-69	23063	1.6-1.7	94	9171	4.78	0.22
35	I-69	23063	2.2-2.3	94	9217	4.86	0.10
35	I-69	23063	2.3-2.4	94	9074	4.02	0.11
35	I-69	76024	2.3-2.4	92	9225	5.08	0.14
35	I-69	76024	2.4-2.5	92	9238	5.3	0.17
35	I-69	76024	2.7-2.8	92	9341	5.82	0.14
35	I-69	76024	3.1-3.2	92	9267	5.1	0.12
35	I-94	11017	1.0-1.1	96	9068	3.98	0.07
35	I-94	11017	1.1-1.2	96	9191	4.77	0.10
35	I-94	11017	1.2-1.3	96	9102	4.15	0.07
35	I-94	11017	2.4-2.5	96	9156	4.36	0.10
35	I-94	11017	3.0-3.1	96	9147	4.7	0.07
35	I-94	11017	3.1-3.2	96	9189	4.81	0.11
45	I-69	23063	0.2-0.3	94	9567	7.28	0.36
45	I-69	23063	3.8-3.9	96	9113	4.41	0.10
45	I-69	23063	3.9-4.0	96	9281	5.31	0.16
45	I-69	76024	0.3-0.4	96	9647	7.62	0.24
45	I-69	76024	3.9-4.0	96	9364	5.78	0.16
45	WB US-10	18024	0.9-1.0	93	9353	5.8	0.23
45	WB US-10	18024	1.1-1.2	93	9484	6.71	0.24
45	EB US-10	18024	3.1-3.2	92	9299	5.33	0.24
45	EB US-10	18024	3.3-3.4	92	9328	5.53	0.26
45	EB US-10	18024	4.5-4.6	92	9273	5.55	0.26
45	EB US-10	18024	3.0-3.1	95	9253	5.14	0.23
45	EB US-10	18024	3.1-3.2	95	9234	5.04	0.22
45	WB US-2	21022	7.8-7.9	93	9600	7.6	0.48
45	EB US-2	21025	2.4-2.5	95	9286	5.9	0.27
45	WB US-2	21025	4.3-4.4	95	9347	5.5	0.25
55	WB US-10	18024	1.1-1.2	95	9437	6.41	0.39
55	WB US-10	18024	4.1-4.2	95	9511	7.11	0.33
55	WB US-10	18024	6.6-6.7	95	9539	7.06	0.37
55	WB US-10	18024	6.8-6.9	95	9529	7.7	0.37
55	WB US-10	18024	7.1-7.2	95	9586	7.16	0.42
55	EB US-10	18024	2.7-2.8	92	9502	7.2	0.47
55	EB US-10	18024	5.5-5.6	92	9703	8.35	0.56
55	EB US-10	18024	6.0-6.1	92	9533	7.92	0.51
55	EB US-10	18024	6.1-6.2	92	9712	8.33	0.72
55	EB US-10	18024	6.6-6.7	92	9602	7.41	0.45
55	EB US-10	18024	7.0-7.1	92	9453	6.68	0.34
55	EB US-10	18024	4.0-4.1	95	9462	6.72	0.33
55	EB US-10	18024	5.3-5.4	95	9660	7.77	0.48
55	EB US-10	18024	6.1-6.2	95	9592	8.24	0.47
55	EB US-10	18024	7.0-7.1	95	9518	6.95	0.40
55	EB US-2	21022	2.0-2.1	93	9628	8.2	0.54

RQI, DLC, 95th Percentile DL and DLI for Rigid Pavement Sections (Continued)

RQI	Route No.	CS	M.P.	Year	95%tile	DLC	DLI
55	EB US-2	21022	7.4-7.5	93	9740	8.4	0.78
55	EB US-2	21025	1.7-1.8	95	9426	6.6	0.34
55	EB US-2	21025	3.6-3.7	95	9553	7.3	0.48
55	EB US-2	21025	3.7-3.8	95	9568	7.8	0.60
55	NB US-31	70014	0.3-0.4	94	9532	7.1	0.38
55	NB US-31	70014	1.6-1.7	94	9666	8.9	0.57
55	NB US-31	70014	3.6-3.7	94	9753	8.6	0.62
65	WB US-10	18024	5.5-5.6	96	9658	8.81	0.63
65	WB US-10	18024	6.0-6.1	96	9846	9.36	0.65
65	WB US-10	18024	7.6-7.7	94	9669	8	0.76
65	WB US-10	18024	2.9-3.0	95	9565	8.24	0.52
65	WB US-10	18024	7.0-7.1	96	9884	11.32	1.10
65	WB US-10	18024	7.4-7.5	96	9877	9.85	0.85
65	EB US-10	18024	0.9-1.0	93	9683	8.75	0.73
65	EB US-10	18024	2.9-3.0	93	9662	8.05	0.69
65	EB US-10	18024	2.0-2.1	94	9521	7.53	0.40
65	EB US-10	18024	0.9-1.0	95	9827	9.1	0.86
65	EB US-10	18024	2.3-2.4	95	9451	6.56	0.30
65	EB US-10	18024	2.9-3.0	95	9697	8.54	0.73
65	EB I-94	11017	3.9-4.0	92	9817	8.76	0.81
65	WB US-2	21022	2.0-2.1	93	9832	9	0.74
65	WB US-2	21022	2.8-2.9	93	9880	9.2	0.68
65	WB US-2	21022	5.0-5.1	93	10197	11	0.99
65	WB US-2	21022	5.1-5.2	93	10276	11.3	1.38
65	WB US-2	21022	6.8-6.9	93	10048	11	1.08
65	NB US-31	70014	5.6-5.7	94	10077	10.3	0.86
65	EB US-2	21025	1.6-1.7	95	10040	10	1.22
75	EB I-94	11017	2.8-2.9	92	10169	11.88	1.22
75	EB I-94	11017	3.4-3.5	93	10024	10.97	1.10
75	EB I-94	11017	1.7-1.8	94	9934	10.57	1.19
75	EB I-94	11017	3.6-3.7	94	10160	11.6	1.38
75	EB I-94	11017	3.9-4.0	94	9905	9.96	0.82
75	EB I-94	11017	4.8-4.9	94	10073	10.92	1.35
75	EB I-94	11017	3.4-3.5	95	10014	10.68	1.19
75	EB US-10	18024	0.5-0.6	93	9947	11.57	1.45
75	EB US-10	18024	7.2-7.3	93	10296	12.32	1.55
75	NB US-31	70014	5.4-5.5	94	10032	10.8	1.51
75	WB I-196 BL	70023	1.6-1.7	95	10135	11.5	1.16
75	WB I-196 BL	70023	2.7-2.8	95	10011	10.3	0.84
75	WB I-196 BL	70023	4.1-4.2	95	9880	9.8	0.96
80	EB I-94	11017	3.7-3.8	93	10106	12.44	1.17
80	EB I-94	11017	3.8-3.9	94	10501	13.54	1.95
80	EB I-94	11017	1.4-1.5	95	10074	11.63	1.25
80	EB I-94	11017	4.2-4.3	95	10178	11.59	1.39
80	WB US-10	18024	2.2-2.3	95	9949	10.51	0.94

RQI, DLC, 95th Percentile DL and DLI for Rigid Pavement Sections (Continued)

RQI	Route No.	CS	M.P.	Year	95%tile	DLC	DLI
80	WB I-196 BL	70023	0.0-0.1	95	10215	15.5	2.39
80	WB I-196 BL	70023	4.3-4.4	95	10353	12.6	1.91
85	EB I-94	11017	5.7-5.8	93	10735	15.72	2.19
85	EB I-94	11017	3.5-3.6	94	10610	15.13	1.85
85	EB I-94	11017	1.3-1.4	95	10146	12.01	1.29
85	EB I-94	11017	1.8-1.9	95	10424	12.95	2.04
90	EB I-94	11017	5.1-5.2	95	10954	18.37	3.24
90	EB I-94	11017	5.9-6.0	95	10759	16.94	2.30
90	EB I-94	11017	5.9-6.0	96	10742	16.02	2.00
90	WB I-196 BL	70023	1.7-1.8	95	10393	14.8	1.78
91	WB I-196 BL	70023	1.5-1.6	95	10824	17.9	2.53
92	WB US-2	21022	5.8-5.9	93	11209	19	3.80
95	EB I-94	11017	5.3-5.4	93	12059	23.13	4.39
95	EB I-94	11017	5.8-5.9	94	11389	20.93	3.78
95	EB I-94	11017	4.9-5.0	95	11876	22.16	5.98
99	EB I-94	11017	4.4-4.5	94	12865	28.77	6.33
99	EB I-94	11017	5.3-5.4	94	12211	24.58	4.90

RQI, DLC, 95th Percentile DL and DLI for Composite Pavement Sections

RQI	Route No.	CS	M.P.	Year	95%tile DL	DLC	DLI
30	EB I-94	38101	7.7-7.8	92	9119	4.3	0.12
30	EB I-94	38101	5.7-5.8	93	9193	5.1	0.18
30	EB I-94	38101	8.2-8.3	93	9277	5.4	0.22
30	NB US-127	38131	3.6-3.7	92	9111	4.3	0.14
30	NB US-127	38131	4.0-4.1	92	9128	4.4	0.14
30	NB US-127	38131	1.0-1.1	94	9124	4.4	0.08
30	SB US-131	78012	0.2-0.3	93	9160	4.9	0.12
30	SB US-131	78012	0.3-0.4	93	9244	4.9	0.18
30	SB US-131	78012	1.1-1.2	93	9576	7.1	0.22
30	SB US-131	78012	1.4-1.5	93	9294	5.6	0.36
30	SB US-131	78012	4.4-4.5	93	9207	4.9	0.29
30	SB US-131	78012	4.7-4.8	93	9271	5.2	0.24
40	EB I-94	38101	1.8-1.9	92	9292	5.5	0.37
40	EB I-94	38101	2.2-2.3	92	9322	5.5	0.22
40	EB I-94	38101	6.1-6.2	92	9444	6.1	0.22
40	EB I-94	38101	2.3-2.4	93	9450	6.6	0.28
40	EB I-94	38101	4.1-4.2	93	9220	5	0.18
40	EB I-94	38101	6.0-6.1	93	9363	6.4	0.40
40	EB I-94	38101	6.8-6.9	93	9378	6.6	0.26
40	EB I-94	38101	1.3-1.4	94	9393	5.9	0.31
40	EB I-94	38101	2.5-2.6	94	9382	6.2	0.25
40	EB I-94	38101	3.3-3.4	94	9306	5.2	0.18
40	EB I-94	38101	5.4-5.5	94	9274	5.7	0.22
40	EB I-94	38101	4.6-4.7	95	9271	5.4	0.30
40	EB I-94	38101	4.9-5.0	95	9338	5.6	0.26
40	EB I-94	38101	5.6-5.7	95	9311	5.5	0.28
40	NB US-127	38131	1.1-1.2	92	9303	5.7	0.19
40	NB US-127	38131	1.5-1.6	93	9335	5.5	0.17
40	M-21	76062	4.0-4.1	96	9275	5.9	0.21
40	SB US-131	78012	1.8-1.9	93	9380	6.4	0.43
40	SB US-131	78012	7.8-7.9	93	9273	5.7	0.30
50	EB I-94	38101	0.5-0.6	92	9506	7.4	0.40
50	EB I-94	38101	0.9-1.0	93	9579	7.1	0.40
50	EB I-94	38101	2.9-3.0	93	9461	7.5	0.36
50	EB I-94	38101	0.0-0.1	94	9568	7.1	0.63
50	EB I-94	38101	1.7-1.8	95	9361	5.8	0.24
50	EB I-94	38101	3.5-3.6	95	9363	6	0.25
50	EB I-94	38101	6.7-6.8	95	9496	7.4	0.34
50	EB I-94	38101	8.4-8.5	95	9284	5.8	0.24
50	NB US-127	38131	0.6-0.7	92	9354	6.4	0.38
50	NB US-127	38131	0.8-0.9	92	9333	6.4	0.38
50	NB US-127	38131	0.9-1.0	92	9199	5.4	0.27
50	NB US-127	38131	0.6-0.7	93	9402	6.5	0.40
50	NB US-127	38131	1.6-1.7	94	9346	5.9	0.25
50	NB US-127	38131	3.5-3.6	95	9380	6	0.26
50	NB US-127	38131	1.8-1.9	96	9270	5.8	0.33
50	NB US-127	38131	3.7-3.8	96	9297	5.4	0.19

RQI, DLC, 95th Percentile DL and DLI for Composite Pavement Sections (Continued)

RQI	Route No.	CS	M.P.	Year	95%tile DL	DLC	DLI
50	M-115	18011	2.6-2.7	96	9453	6.9	0.45
50	M-115	18011	7.5-7.6	96	9500	6.7	0.38
50	M-21	76062	3.4-3.5	96	9489	6.9	0.34
50	M-21	76062	6.3-3.4	96	9430	6.9	0.31
50	M-21	76062	9.0-9.1	96	9379	6.8	0.67
50	M-21	76062	10.3-10.4	96	9560	7.2	0.44
50	SB US-131	78012	3.4-3.5	93	10013	10.2	0.81
50	SB US-131	78012	7.0-7.1	93	9435	6.6	0.25
60	EB I-94	38101	7.1-7.2	92	9577	7.1	0.28
60	EB I-94	38101	2.0-2.1	94	9728	8.5	0.72
60	EB I-94	38101	0.5-0.6	95	9774	8.6	0.56
60	NB US-127	38131	4.3-4.4	92	9487	7.2	0.38
60	NB US-127	38131	3.9-4.0	93	9340	6.9	0.28
60	NB US-127	38131	0.3-0.4	94	9618	9.3	0.85
60	NB US-127	38131	3.3-3.4	94	9458	8.9	0.61
60	NB US-127	38131	4.9-5.0	94	9500	9	0.71
60	NB US-127	38131	2.4-2.5	95	9335	7.2	0.44
60	NB US-127	38131	5.1-5.2	95	9447	7.4	0.57
60	NB US-127	38131	0.2-0.3	96	9959	10.2	0.92
60	NB US-127	38131	3.3-3.4	96	9256	7.8	0.48
60	NB US-127	38131	4.2-4.3	96	9365	6.7	0.31
60	NB US-127	38131	4.6-4.7	96	9542	7.6	0.60
60	US-12	11011	2.2-2.3	96	9611	7.7	0.51
60	M-115	18011	0.1-0.2	96	9627	7.8	0.61
60	M-115	18011	1.0-1.1	96	9804	9.1	0.77
60	M-115	18011	8.2-8.3	96	9607	7.6	0.40
60	M-21	76062	2.6-2.7	96	9940	9.7	1.19
60	M-52	78012	6.0-6.1	93	9369	7.3	0.45
60	M-52	78012	7.4-7.5	93	9519	7.7	0.53
70	M-115	18011	0.0-0.1	96	9947	9.6	0.82
70	M-115	18011	1.3-1.4	96	9725	9.5	0.81
70	M-115	18011	5.4-5.5	96	10098	10.9	1.08
70	M-115	18011	5.9-6.0	96	9821	11.1	1.09
70	M-115	18011	6.0-6.1	96	9896	10.5	1.30
70	M-115	18011	8.0-8.1	96	9961	10.9	1.17
70	M-95	22012	13.4-13.5	96	9963	10.4	1.77
70	M-95	22012	13.7-13.8	96	9527	8.3	0.70
70	M-52	76012	7.3-7.4	96	9679	9.7	0.71
70	M-21	76062	3.2-3.3	96	10169	11.7	1.63
70	SB US-131	78012	3.5-3.6	93	10764	15.7	2.32
70	SB US-131	78012	8.6-8.7	93	9819	9.8	0.85
80	M-52	76012	0.7-0.8	96	10973	14.6	2.51
80	SB US-131	78012	9.8-9.9	93	10243	13.4	1.48
81	M-52	76012	5.7-5.8	96	9980	12.6	1.14
81	SB US-131	78012	2.9-3.0	93	11700	19.6	3.48
82	M-115	18011	8.9-9.0	96	10361	13.6	2.49

RQI, DLC, 95th Percentile DL and DLI for Composite Pavement Sections (Continued)

RQI	Route No.	CS	M.P.	Year	95%tile DL	DLC	DLI
82	M-95	22012	15.4-15.5	96	9654	10.3	1.11
82	SB US-131	78012	9.4-9.5	93	10123	13.2	1.71
83	SB US-131	78012	9.0-9.1	93	10423	13.7	2.14
84	M-21	76062	12.4-12.5	96	10179	13.6	2.11
84	SB US-131	78012	3.0-3.1	93	11387	19.2	3.63
85	M-21	76062	0.8-0.9	96	10565	16.3	2.36
86	SB US-131	78012	9.7-9.8	93	10574	14.7	1.78
87	M-115	18011	6.6-6.7	96	10170	14	1.39
87	SB US-131	78012	2.4-2.5	93	10901	17.9	5.21
87	SB US-131	78012	2.7-2.8	93	11184	18.8	3.47
87	SB US-131	78012	9.2-9.3	93	10283	14.1	2.16
89	M-21	76062	0.7-0.8	96	11261	18.5	2.35
90	M-21	76062	1.0-1.1	96	11218	19.1	3.33
93	M-21	76062	0.9-1.0	96	11553	20	4.44
95	SB US-131	78012	3.1-3.2	93	10936	18.1	5.64
96	M-21	76062	0.6-0.7	96	11275	19.4	3.45
99	M-52	76012	0.0-0.1	96	12616	30.8	9.85
103	M-21	76062	0.4-0.5	96	12517	25	6.46
104	SB US-131	78012	2.5-2.6	93	12882	31	7.58
104	SB US-131	78012	2.6-2.7	93	12394	24.3	5.69

RQI, DLC, 95th Percentile DL and DLI for Flexible Pavement Sections

RQI	Route No.	CS	M.P.	Year	95th% DL	DLC	DLI
20	EB US-10	09101	2.5-2.6	92	9093	4.2	0.11
20	EB US-10	09101	2.8-2.9	92	9019	3.6	0.07
20	EB US-10	09101	3.1-3.2	93	9053	3.8	0.13
20	EB US-10	09101	4.4-4.5	93	9220	4.5	0.20
20	EB I-96	33084	9.3-9.4	94	9165	4.5	0.07
20	EB I-96	33084	12.1-12.2	94	9088	3.9	0.08
20	EB I-96	33084	13.7-13.8	94	9029	3.6	0.08
20	EB I-96	33084	14.1-14.2	94	8959	3.2	0.15
20	EB I-96	33084	15.4-15.5	96	8886	2.8	0.04
30	EB US-10	09101	1.9-2.0	92	9141	5.2	0.19
30	EB US-10	09101	4.9-5.0	92	9322	5.7	0.23
30	EB US-10	09101	5.1-5.2	92	9207	4.9	0.22
30	EB US-10	09101	5.6-5.7	92	9256	5.2	0.22
30	EB US-10	09101	0.9-1.0	93	9399	6.2	0.51
30	EB US-10	09101	3.0-3.1	93	9330	5.5	0.16
30	EB US-10	09101	4.6-4.7	94	9224	4.8	0.38
30	EB US-10	09101	6.0-6.1	94	9296	5.4	0.20
30	EB I-96	33084	9.2-9.3	95	9128	4.2	0.09
30	EB I-96	33084	10.5-10.6	95	9113	4.1	0.10
30	EB I-96	33084	12.1-12.2	95	9220	4.7	0.11
30	EB I-96	33084	12.3-12.4	95	9030	3.7	0.11
30	EB I-96	33084	14.3-14.4	95	9046	3.8	0.09
30	EB I-96	33084	16.3-16.4	95	9101	4.1	0.13
30	EB I-96	33084	17.2-17.3	95	9188	4.8	0.09
30	NB US-23	47014	4.2-4.3	94	9243	5.2	0.17
30	NB US-23	47014	5.8-5.9	94	9201	4.7	0.21
30	NB US-23	47014	6.7-6.8	94	9273	5.5	0.16
30	NB US-23	47014	7.0-7.1	94	9277	5.1	0.15
30	M-30	26032	12.4-12.5	96	9194	5	0.20
30	M-57	29022	8.5-8.6	96	9170	4.5	0.10
30	M-28	31021	8.4-8.5	95	9168	4.2	0.12
40	EB US-10	09101	3.5-3.6	95	9413	6.1	0.22
40	EB US-10	09101	1.4-1.5	92	9366	6.9	0.16
40	EB US-10	09101	1.6-1.7	92	9403	7.1	0.40
40	EB US-10	09101	3.4-3.5	92	9432	5.9	0.25
40	EB US-10	09101	6.8-6.9	92	9565	6.6	0.46
40	EB US-10	09101	1.6-1.7	93	9554	7.1	0.84
40	EB I-96	33084	13.3-13.4	95	9466	5.8	0.33
40	NB US-23	47014	0.2-0.3	93	9401	6.3	0.16
40	NB US-23	47014	1.7-1.8	93	9355	6.4	0.33
40	NB US-23	47014	2.4-2.5	93	9526	6.9	0.52
40	NB US-23	47014	4.4-4.5	93	9450	7.4	0.46
40	NB US-23	47014	1.8-1.9	95	9487	6.7	0.37
40	NB US-23	47014	1.9-2.0	95	9475	6.1	0.38
40	NB US-23	47014	2.5-2.6	95	9562	6	0.62
40	NB US-23	47014	4.5-4.6	95	9377	3.9	0.38
40	NB US-23	47014	6.1-6.2	95	9417	6.3	0.22

RQI, DLC, 95th Percentile DL and DLI for Flexible Pavement Sections (Continued)

RQI	Route No.	CS	M.P.	Year	95th% DL	DLC	DLI
40	NB US-23	47014	7.0-7.1	95	9542	6.3	0.62
40	M-57	25102	6.8-6.9	96	9266	5	0.22
40	M-57	25102	7.9-8.0	96	9219	5.5	0.17
40	M-30	26032	0.3-0.4	96	9321	5.5	0.17
40	M-30	26032	0.5-0.6	96	9289	5.5	0.27
40	M-28	31021	0.0-0.1	95	9378	6.3	0.76
40	M-28	31021	8.6-8.7	95	9233	5.5	0.20
50	NB US-23	47014	4.2-4.3	96	9327	6	0.23
50	M-88	05031	19.0-19.1	96	9667	7.6	0.67
50	M-95	22013	9.7-9.8	94	9479	6.6	0.35
50	M-57	25102	1.2-1.3	96	9580	7.7	0.44
50	M-57	25102	1.3-1.4	96	9483	6.7	0.38
50	M-57	25102	4.7-4.8	96	9388	6.2	0.30
50	M-30	26032	7.5-7.6	96	9748	8.9	0.64
50	M-30	26032	9.3-9.4	96	9217	6.9	0.35
50	M-57	29022	0.7-0.8	96	9376	6	0.26
50	M-57	29022	1.5-1.6	96	9178	5	0.19
50	M-57	29022	1.6-1.7	96	9431	6.3	0.27
50	M-28	31021	3.1-3.2	95	9527	6.9	0.42
50	M-28	31021	4.3-4.4	95	9683	7.8	0.54
50	M-65	35012	9.7-9.8	96	9829	9.4	0.88
50	M-65	35012	12.9-13.0	96	9755	9.5	0.91
50	M-65	35012	14.7-14.8	96	9714	8.2	0.89
60	M-95	22013	3.2-3.3	94	9696	8.2	0.42
60	M-95	22013	10.3-10.4	94	9824	8.8	0.62
60	M-57	25102	1.4-1.5	96	9652	8.1	0.62
60	M-57	25102	3.9-4.0	96	9662	8.1	0.57
60	M-57	25102	8.4-8.5	96	9451	6.8	0.71
60	M-57	25102	8.8-8.9	96	9598	7.4	0.71
60	M-30	26032	7.3-7.4	96	9738	8.7	0.74
60	M-28	31021	2.7-2.8	95	9703	8.6	0.85
60	M-28	31021	9.0-9.1	95	9554	8.4	0.75
60	M-28	31021	9.5-9.6	95	9779	8.7	0.60
60	M-65	35012	8.9-9.0	96	10248	11.2	0.92
60	M-65	35012	12.0-12.1	96	9983	10.1	1.15
60	M-65	35012	15.8-15.9	96	10022	9.7	1.18
60	NB US-31	61074	0.4-0.5	96	9424	6.7	0.42
60	NB US-31	61074	2.0-2.1	96	9703	7.9	0.64
60	NB US-27	72014	0.5-0.6	96	9747	7.9	0.47
60	NB US-27	72014	1.5-1.6	96	9684	8.3	0.54
60	NB US-27	72014	5.6-5.7	96	9644	8.3	0.41
70	M-57	25102	4.9-5.0	96	10001	10.5	1.16
70	M-57	25102	8.9-9.0	96	9703	9	0.68
70	M-65	35012	8.5-8.6	96	9872	12.1	1.22
70	NB US-27	72014	0.6-0.7	96	10065	10.8	0.97
75	M-88	05031	19.7-19.8	96	9913	10.6	1.29

RQI, DLC, 95th Percentile DL and DLI for Flexible Pavement Sections (Continued)

RQI	Route No.	CS	M.P.	Year	95th% DL	DLC	DLI
75	M-95	22013	8.7-8.8	94	10801	15.5	1.95
75	NB US-27	72014	0.4-0.5	96	10295	11.7	1.04
76	M-95	22013	9.3-9.4	94	10216	12.3	1.29
76	M-57	25102	4.5-4.6	96	9887	11.5	1.44
76	M-57	25102	5.7-5.8	96	10241	13.3	1.51
76	M-65	35012	7.8-7.9	96	10470	14.2	1.72
77	M-95	22013	9.0-9.1	94	10613	14.1	1.88
77	NB US-27	72014	0.0-0.1	96	10194	12.2	1.08
77	NB US-27	72014	0.2-0.3	96	10039	11.2	1.28
78	M-95	22013	9.1-9.2	94	11443	18.2	2.80
79	M-95	22013	8.8-8.9	94	10337	13.9	1.66
79	M-95	35012	7.0-7.1	96	11186	17.4	3.33
80	M-95	35012	15.2-15.3	96	10880	14.9	2.09
81	M-65	35012	13.6-13.7	96	11248	17.1	3.32
82	M-88	05031	19.8-19.9	96	10287	14.8	2.82
82	M-65	35012	15.1-15.2	96	10769	16.1	2.26
83	M-57	25102	8.6-8.7	96	10807	15.5	2.64
88	M-95	22013	9.2-9.3	94	11411	20.4	3.54

APPENDIX F
RQI INCREASE RATE FOR RIGID PAVEMENTS

RQI Increase Rate for Rigid Pavements

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	98	93-92	94-93	95-94	96-95	94-92	95-93	96-94	95-92	98-93	96-92
19042n	0.5	46.4	48.2	47.8	51.0	48.2	1.8	-0.4	3.2	-2.8	1.4	2.8	0.4	4.8	0.0	1.8
	1	49.0	47.6	51.4	56.8	51.2	-1.4	3.8	5.4	-5.8	2.4	9.2	-0.2	7.8	3.6	2.2
	1.5	47.6	46.6	48.6	50.4	50.0	-1.0	2.0	1.8	-0.4	1.0	3.8	1.4	2.8	3.4	2.4
	2	48.6	47.8	50.8	51.6	52.2	-0.8	3.0	0.8	0.8	2.2	3.8	1.4	3.0	4.4	3.6
	2.5	45.8	45.8	48.6	52.2	51.4	0.0	2.8	3.8	-0.8	2.8	6.4	2.8	6.4	5.6	5.6
	3	51.0	48.8	52.6	56.0	54.4	-2.4	4.0	3.4	-1.6	1.8	7.4	1.8	5.0	5.8	3.4
	3.5	48.0	47.6	50.2	51.2	50.2	-0.4	2.6	1.0	-1.0	2.2	3.8	0.0	3.2	2.6	2.2
	4	49.6	49.2	51.4	55.6	51.2	-0.4	2.2	4.2	-4.4	1.8	6.4	-0.2	8.0	2.0	1.6
	4.5	46.8	47.0	49.6	54.6	52.4	0.2	2.6	5.0	-2.2	2.8	7.8	2.8	7.8	5.4	5.6
	5	48.2	48.0	50.6	56.6	53.2	-0.2	2.6	6.0	-3.4	2.4	8.6	2.8	8.4	5.2	5.0
	5.5	45.2	47.8	47.4	53.8	50.2	2.6	-0.4	6.4	-3.6	2.2	8.0	2.8	8.6	2.4	5.0
	6	46.0	46.2	47.8	50.8	50.8	0.2	1.6	3.0	0.0	1.8	4.8	3.0	4.8	4.8	4.8
	6.5	49.2	48.0	49.2	50.8	50.2	-1.2	1.2	1.6	-0.6	0.0	2.8	1.0	1.6	2.2	1.0
	7	48.2	47.8	50.4	51.4	52.6	-0.4	2.6	1.0	1.2	2.2	3.6	2.2	3.2	4.8	4.4
19042s	0	44.0	45.2	45.8	45.8	47.4	1.2	0.8	0.0	1.7	1.8	0.5	1.6	1.8	2.2	3.4
	0.5	48.5	51.8	52.3	54.0	43.0	3.3	0.5	1.8	-11.0	3.8	2.3	-9.3	5.5	-8.8	-5.5
	1	47.6	48.8	49.4	51.8	53.4	-1.0	2.8	2.4	1.6	1.8	5.2	4.0	4.2	6.8	5.8
	1.5	39.6	38.6	42.4	48.2	46.6	-1.0	3.8	5.8	-1.6	2.8	9.6	4.2	8.6	8.0	7.0
	2	44.6	42.6	45.2	50.4	48.4	-2.0	2.6	5.2	-2.0	0.6	7.8	3.2	5.8	5.8	3.8
	2.5	51.4	51.2	52.8	55.4	53.8	-0.2	1.6	2.6	-1.6	1.4	4.2	1.0	4.0	2.6	2.4
	3	46.8	46.8	47.6	50.4	50.4	0.0	0.8	2.8	0.0	0.8	3.6	2.8	3.6	3.6	3.6
	3.5	48.4	46.8	49.2	51.4	51.0	-1.6	2.4	2.2	-0.4	0.8	4.6	1.8	3.0	4.2	2.6
	4	49.4	48.8	51.8	57.0	52.2	-0.8	3.0	5.2	-4.8	2.4	8.2	0.4	7.6	3.4	2.8
	4.5	46.6	46.8	48.6	48.0	51.6	0.2	1.8	-0.6	3.6	2.0	1.2	3.0	1.4	4.8	5.0
	5	45.8	44.8	46.6	49.2	48.8	-1.0	1.8	2.6	-0.6	0.8	4.4	2.0	3.4	3.8	2.8
	5.5	49.0	48.8	51.0	52.2	52.4	-0.4	2.4	1.2	0.2	2.0	3.8	1.4	3.2	3.8	3.4
	6	47.8	48.8	50.2	53.8	52.8	1.0	1.4	3.6	-1.2	2.4	5.0	2.4	8.0	3.8	4.8
	6.5	50.6	49.6	52.0	56.0	54.2	-1.0	2.4	4.0	-1.8	1.4	6.4	2.2	5.4	4.6	3.6
	7	55.4	54.2	56.4	55.4	57.2	-1.2	2.2	-1.0	1.8	1.0	1.2	0.8	0.0	3.0	1.8
	7.5	51.2	51.2	52.8	54.4	54.2	0.0	1.6	1.6	-0.2	1.8	3.2	1.4	3.2	3.0	3.0
34043e	0	41.8	43.5	41.8	52.0	47.3	1.8	-1.8	10.3	-4.8	0.0	8.5	5.5	10.3	3.8	5.5
	0.5	43.8	44.0	44.4	45.4	47.4	0.2	0.4	1.0	2.0	0.6	1.4	3.0	1.6	3.4	3.6
	1	37.4	39.0	40.2	40.6	44.0	1.6	1.2	0.4	3.4	2.8	1.8	3.8	3.2	5.0	6.6
	1.5	43.4	41.8	44.4	44.8	46.0	-1.6	2.6	0.4	1.2	1.0	3.0	1.6	1.4	4.2	2.6
	2	46.0	45.8	47.2	49.2	49.8	-0.2	1.4	2.0	0.6	1.2	3.4	2.6	3.2	4.0	3.8
	2.5	46.4	47.4	47.6	50.2	51.0	1.0	0.2	2.6	0.8	1.2	2.8	3.4	3.8	3.6	4.6
	3	41.2	40.8	41.8	45.0	49.0	-0.4	1.0	3.2	4.0	0.6	4.2	7.2	3.8	8.2	7.8
	3.5	44.2	46.0	45.8	46.4	50.2	1.8	-0.2	0.6	3.8	1.6	0.4	4.4	2.2	4.2	6.0
	4	44.8	44.8	46.4	48.4	49.8	0.0	1.6	2.0	1.4	1.6	3.6	3.4	3.6	5.0	5.0
	4.5	45.2	45.8	47.4	49.0	50.2	0.6	1.6	1.6	1.2	2.2	3.2	2.8	3.8	4.4	5.0
	5	48.4	50.8	51.6	53.4	54.0	2.4	0.8	1.8	0.6	3.2	2.6	2.4	5.0	3.2	5.6
	5.5	47.2	48.6	47.8	48.8	52.8	1.4	-0.8	1.0	4.0	0.6	0.2	5.0	1.6	4.2	5.6
	6	42.2	43.4	44.0	47.2	46.6	1.2	0.6	3.2	-0.8	1.8	3.8	2.6	5.0	3.2	4.4
	6.5	43.8	45.4	45.4	50.4	50.0	1.6	0.0	5.0	-0.4	1.6	5.0	4.6	8.6	4.6	6.2

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	96	93-92	94-93	95-94	98-95	94-92	95-93	96-94	95-92	96-93	96-92
34043w	0	41.8	42.6	43.6	47.6	48.0	0.9	1.0	4.0	0.4	1.9	5.0	4.4	5.9	5.4	8.3
	0.5	38.8	38.6	39.0	41.2	41.8	-0.2	0.4	2.2	0.4	0.2	2.6	2.8	2.4	3.0	2.8
	1	45.0	42.2	43.8	49.2	46.6	-2.8	1.6	5.4	-2.6	-1.2	7.0	2.8	4.2	4.4	1.6
	1.5	42.8	42.6	42.8	47.8	48.0	-0.2	0.2	5.0	0.2	0.0	5.2	5.2	5.0	5.4	5.2
	2	42.4	42.0	44.0	48.8	49.2	-0.4	2.0	4.8	0.4	1.8	6.8	5.2	6.4	7.2	8.8
	2.5	43.0	42.8	44.4	47.8	48.2	-0.2	1.6	3.4	0.4	1.4	5.0	3.8	4.8	5.4	5.2
	3	45.8	47.4	47.8	49.4	50.0	1.8	0.4	1.6	0.6	2.0	2.0	2.2	3.6	2.8	4.2
	3.5	45.6	44.8	46.8	49.4	51.2	-0.8	2.0	2.6	1.8	1.2	4.6	4.4	3.8	6.4	5.6
	4	39.8	40.0	40.2	46.8	45.6	0.2	0.2	6.6	-1.2	0.4	6.8	5.4	7.0	5.6	5.8
	4.5	46.0	45.0	45.2	50.6	50.8	-1.0	0.2	5.4	0.2	-0.8	5.6	5.6	4.6	5.8	4.8
	5	44.6	45.6	44.4	49.4	50.4	1.0	-1.2	5.0	1.0	-0.2	3.8	6.0	4.8	4.8	5.8
	5.5	43.0	44.4	46.8	48.8	51.0	1.4	2.4	2.0	2.2	3.8	4.4	4.2	5.8	6.6	8.0
	6	43.8	44.2	46.6	50.6	53.6	0.4	2.4	4.0	3.0	2.8	6.4	7.0	6.8	9.4	9.8
	6.5	40.8	39.2	41.8	45.6	46.6	-1.6	2.6	3.8	1.0	1.0	6.4	4.8	4.8	7.4	5.8
80024e	5.5	49.0	52.2	49.0	52.6	57.8	3.2	-3.2	3.8	5.2	0.0	0.4	8.8	3.6	5.6	8.8
	6	46.6	49.0	47.4	49.8	52.2	2.4	-1.6	2.4	2.4	0.8	0.8	4.8	3.2	3.2	5.6
	6.5	48.8	54.0	55.8	51.8	55.8	5.2	1.8	-4.0	3.8	7.0	-2.2	-0.2	3.0	1.6	6.8
	7	50.8	52.8	57.8	54.4	59.6	2.0	5.0	-3.4	5.2	7.0	1.6	1.8	3.6	6.8	8.8
	7.5	47.0	49.6	57.6	51.2	55.2	2.6	8.0	-6.4	4.0	10.6	1.6	-2.4	4.2	5.8	8.2
	8	48.6	49.8	50.0	52.8	57.2	1.2	0.2	2.8	4.4	1.4	3.0	7.2	4.2	7.4	8.6
	8.5	49.8	50.8	47.6	52.8	55.8	1.0	-3.2	5.2	2.8	-2.2	2.0	8.0	3.0	4.8	5.8
	9	51.6	52.8	52.2	57.0	61.2	1.2	-0.6	4.8	4.2	0.6	4.2	9.0	5.4	8.4	9.6
	9.5	51.0	51.8	53.4	56.8	58.8	0.8	1.6	3.4	2.0	2.4	5.0	5.4	5.8	7.0	7.8
	10	49.4	50.2	48.8	53.2	56.2	0.8	-1.5	4.5	3.0	-0.6	3.0	7.5	3.8	6.0	6.8
34044e	3	44.6	47.0	44.4	49.0	49.0	2.4	-2.8	4.8	0.0	-0.2	2.0	4.6	4.4	2.0	4.4
	3.5	49.2	49.6	51.4	55.2	58.2	0.4	1.8	3.8	3.0	2.2	5.6	6.8	6.0	8.6	9.0
	4	44.8	45.8	45.0	49.8	52.6	1.0	-0.8	4.8	2.8	0.2	4.0	7.6	5.0	6.8	7.8
	4.5	42.2	45.4	43.6	47.6	48.0	3.2	-1.8	4.0	0.4	1.4	2.2	4.4	5.4	2.6	5.8
	5	50.2	54.0	55.0	56.0	56.6	3.8	1.0	1.0	0.6	4.8	2.0	1.8	5.8	2.6	6.4
	5.5	50.0	53.3	51.0	52.5	53.8	3.3	-2.3	1.5	1.3	1.0	-0.8	2.8	2.5	0.5	3.8
	6	49.8	51.6	51.2	52.6	55.2	1.8	-0.4	1.4	2.6	1.4	1.0	4.0	2.8	3.6	5.4
	6.5	44.8	46.2	47.4	47.2	48.8	1.4	1.2	-0.2	1.6	2.6	1.0	1.4	2.4	2.6	4.0
	7	44.8	47.2	46.0	47.6	49.4	2.4	-1.2	1.6	1.8	1.2	0.4	3.4	2.8	2.2	4.6
	7.5	44.0	45.8	48.4	46.8	47.4	1.8	2.6	-1.6	0.6	4.4	1.0	-1.0	2.8	1.6	3.4
	8	41.7	49.0	46.5	44.0	45.7	7.3	-2.5	-2.5	1.7	4.8	-5.0	-0.8	2.3	-3.3	4.0
	8.5	46.3	49.8	48.5	49.8	52.3	3.5	-1.3	1.3	2.5	2.3	0.0	3.8	3.5	2.5	6.0
	9	47.5	46.0	45.0	46.5	47.0	-1.5	-1.0	1.5	0.5	-2.5	0.5	2.0	-1.0	1.0	-0.5
	9.5	46.3	49.3	49.3	49.0	50.0	2.9	0.1	-0.3	1.0	3.0	-0.3	0.7	2.7	0.8	3.7
	10	43.0	50.3	43.3	43.7	N.A.	7.3	-7.0	0.3	N.A.	0.3	-6.7	N.A.	0.7	N.A.	N.A.
	10.5	41.6	43.4	43.2	46.8	48.0	1.8	-0.2	3.6	1.2	1.6	3.4	4.8	5.2	4.6	6.4
	11	42.2	43.4	45.6	46.2	46.8	1.2	2.2	0.6	0.6	3.4	2.8	1.2	4.0	3.4	4.6
	11.5	42.4	46.8	46.2	51.4	51.0	4.4	-0.6	5.2	-0.4	3.8	4.6	4.8	9.0	4.2	8.6
	12	45.0	47.2	47.2	47.8	50.8	2.2	0.0	0.6	3.0	2.2	0.6	3.6	2.8	3.6	5.8
	12.5	42.4	45.4	48.0	51.2	52.0	3.0	2.6	3.2	0.8	5.6	5.8	4.0	8.8	6.6	9.6
	13	43.0	43.4	45.0	43.2	45.0	0.4	1.6	-1.8	1.8	2.0	-0.2	0.0	0.2	1.6	2.0

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	96	93-92	94-93	95-94	96-95	94-92	95-93	96-94	95-92	96-93	96-92
13082e'	6.5	43.6	45.8	49.2	52.4	57.8	2.2	3.4	3.2	5.2	5.6	6.6	8.4	8.8	11.6	14.0
	7	47.8	52.8	52.2	57.4	64.2	5.0	-0.6	5.2	6.8	4.4	4.8	12.0	9.6	11.4	18.4
	7.5	44.2	50.4	47.8	54.0	57.2	6.2	-2.8	6.2	3.2	3.6	3.6	9.4	9.8	6.8	13.0
	8	45.2	55.2	55.6	61.6	65.8	10.0	0.4	6.0	4.2	10.4	6.4	10.2	16.4	10.6	20.6
	8.5	43.6	50.4	47.0	53.0	57.0	6.8	-3.4	6.0	4.0	3.4	2.6	10.0	9.4	6.6	13.4
	9	47.2	51.4	52.6	55.6	58.0	4.2	1.2	3.0	2.4	5.4	4.2	5.4	8.4	6.6	10.8
	9.5	42.4	43.4	49.8	52.4	54.2	1.0	6.4	2.6	1.8	7.4	9.0	4.4	10.0	10.8	11.8
	10	44.4	44.6	44.8	50.8	52.8	0.2	0.2	6.0	2.0	0.4	6.2	8.0	6.4	8.2	8.4
	10.5	45.4	48.8	46.6	52.6	55.2	3.4	-2.2	6.0	2.6	1.2	3.8	8.6	7.2	6.4	9.8
	11	47.0	53.8	51.4	56.2	59.8	6.8	-2.4	4.8	3.6	4.4	2.4	8.4	9.2	6.0	12.8
13082w2	6.5	46.4	51.0	52.8	58.8	63.6	4.6	1.8	6.0	4.8	6.4	7.8	10.8	12.4	12.8	17.2
	7	45.4	50.2	50.8	58.6	59.8	4.8	0.6	7.8	1.2	5.4	8.4	9.0	13.2	9.6	14.4
	7.5	46.2	47.6	50.2	55.2	58.4	1.4	2.6	5.0	1.2	4.0	7.6	6.2	9.0	8.8	10.2
	8	48.6	50.0	52.8	54.6	59.4	1.4	2.8	1.8	4.8	4.2	4.6	6.6	6.0	9.4	10.8
	8.5	45.8	48.2	50.2	53.0	56.8	2.4	2.0	2.8	3.8	4.4	4.8	6.6	7.2	8.6	11.0
	9	46.0	48.8	49.6	54.2	57.4	2.6	1.0	4.6	3.2	3.6	5.8	7.8	8.2	8.8	11.4
	9.5	48.4	48.6	50.2	54.0	51.6	0.2	1.6	3.8	-2.4	1.8	5.4	1.4	5.6	3.0	3.2
	10	42.2	42.8	45.4	49.0	48.8	0.6	2.6	3.6	-0.2	3.2	6.2	3.4	6.8	6.0	6.6
	10.5	43.2	43.8	46.8	52.0	52.4	0.6	3.0	5.2	0.4	3.6	8.2	5.6	8.8	8.6	9.2
	11	40.4	41.4	42.4	45.6	46.0	1.0	1.0	3.2	0.4	2.0	4.2	3.6	5.2	4.6	5.6
13083e	5.5	41.4	39.2	40.2	45.6	48.4	-2.2	1.0	5.4	2.8	-1.2	6.4	8.2	4.2	9.2	7.0
	6	59.2	63.8	64.2	64.4	69.0	4.6	0.4	0.2	4.6	5.0	0.6	4.8	5.2	5.2	9.8
	6.5	59.6	62.2	63.4	61.8	63.2	2.6	1.2	-1.6	1.4	3.8	-0.4	-0.2	2.2	1.0	3.6
	7	59.8	60.8	63.4	64.2	66.4	1.2	2.6	0.8	2.2	3.8	3.4	3.0	4.6	5.6	6.8
	7.5	64.2	64.6	66.6	67.8	69.0	0.4	2.0	1.2	1.2	2.4	3.2	2.4	3.6	4.4	4.8
	8	56.4	56.6	59.4	60.2	61.6	0.2	2.8	0.8	1.4	3.0	3.6	2.2	3.8	5.0	5.2
	8.5	59.2	61.4	63.6	63.8	65.0	2.2	2.2	0.2	1.2	4.4	2.4	1.4	4.6	3.8	5.8
	9	64.0	64.4	68.4	65.2	68.6	0.4	4.0	-3.2	3.4	4.4	0.8	0.2	1.2	4.2	4.6
	9.5	64.4	66.4	69.0	69.4	70.4	2.0	2.6	0.4	1.0	4.6	3.0	1.4	5.0	4.0	6.0
	10	57.8	57.2	60.2	60.2	63.2	-0.6	3.0	0.0	3.0	2.4	3.0	3.0	2.4	6.0	5.4
	10.5	58.8	59.6	60.0	62.2	62.0	0.8	0.4	2.2	-0.2	1.2	2.6	2.0	3.4	2.4	3.2
	11	61.8	62.4	63.4	63.4	64.6	0.6	1.0	0.0	1.2	1.6	1.0	1.2	1.6	2.2	2.8
13083w	5.5	35.4	38.6	38.2	38.8	43.6	3.2	-0.4	0.6	4.8	2.8	0.2	5.4	3.4	5.0	8.2
	6	60.2	60.4	61.8	59.6	63.6	0.2	1.4	-2.2	4.0	1.6	-0.6	1.8	-0.8	3.2	3.4
	6.5	60.4	59.8	61.4	62.0	63.6	-0.6	1.6	0.6	1.6	1.0	2.2	2.2	1.6	3.8	3.2
	7	57.3	56.2	58.0	58.8	61.4	-1.1	1.8	0.6	2.6	0.7	2.4	3.4	1.3	5.2	4.1
	7.5	55.8	54.6	56.4	55.6	59.8	-1.2	1.8	-0.8	4.2	0.6	1.0	3.4	-0.2	5.2	4.0
	8	53.4	54.0	54.8	57.4	58.4	0.6	0.8	2.6	1.0	1.4	3.4	3.6	4.0	4.4	5.0
	8.5	52.4	52.2	53.8	53.6	56.6	-0.2	1.4	0.0	3.0	1.2	1.4	3.0	1.2	4.4	4.2
	9	53.8	54.0	55.8	55.4	59.8	0.4	1.8	-0.4	4.4	2.2	1.4	4.0	1.8	5.8	6.2
	9.5	51.8	52.4	56.4	56.0	58.6	0.6	4.0	-0.4	2.6	4.6	3.6	2.2	4.2	6.2	6.8
	10	51.6	50.0	52.4	53.0	55.3	-1.6	2.4	0.6	2.3	0.8	3.0	2.9	1.4	5.3	3.7
	10.5	51.8	50.4	51.4	55.8	58.6	-1.4	1.0	4.4	2.8	-0.4	5.4	7.2	4.0	8.2	6.8
	11	54.0	53.6	55.4	53.8	58.2	-0.4	1.8	-1.6	4.4	1.4	0.2	2.8	-0.2	4.6	4.2

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	96	93-92	94-93	95-94	96-95	94-92	95-93	96-94	95-92	96-93	96-92
44044e	0.5	39.0	40.6	39.0	45.8	44.3	1.6	-1.6	8.8	-1.4	0.0	5.2	5.3	6.8	3.7	5.3
	1	34.3	39.0	42.8	47.4	45.4	4.8	3.8	4.8	-2.0	8.4	8.4	2.8	13.2	8.4	11.2
	1.5	38.4	39.4	40.6	46.2	44.6	3.0	1.2	5.6	-1.6	4.2	8.8	4.0	9.8	5.2	8.2
	2	35.0	33.6	35.2	43.8	42.0	-1.4	1.6	8.8	-1.8	0.2	10.2	6.8	8.8	8.4	7.0
	2.5	39.8	40.4	40.8	49.0	51.6	0.6	0.4	8.2	2.6	1.0	8.6	10.8	9.2	11.2	11.8
	3	37.8	38.3	40.5	46.0	43.3	0.5	2.3	5.5	-2.8	2.8	7.8	2.8	8.3	5.0	5.5
	3.5	37.8	40.8	44.4	52.0	55.4	3.0	3.6	7.6	3.4	6.6	11.2	11.0	14.2	14.6	17.6
	4	42.4	44.0	44.2	53.8	53.4	1.6	0.2	9.8	-0.4	1.8	9.8	9.2	11.4	9.4	11.0
	4.5	38.8	41.6	42.8	47.8	49.4	2.8	1.2	5.0	1.6	4.0	8.2	6.6	9.0	7.8	10.6
	5	38.6	38.0	41.2	45.4	45.0	-0.6	3.2	4.2	-0.4	2.6	7.4	3.8	6.8	7.0	6.4
	5.5	45.4	48.2	48.2	55.2	58.0	2.8	0.0	7.0	2.8	2.8	7.0	9.8	9.8	9.8	12.8
	6	45.6	50.4	51.6	51.8	56.2	4.8	1.2	0.2	4.4	8.0	1.4	4.6	8.2	5.8	10.6
	6.5	50.2	51.2	53.4	59.6	59.8	1.0	2.2	6.2	0.2	3.2	8.4	6.4	9.4	8.6	9.8
	7	49.8	51.2	52.4	53.4	57.0	1.4	1.2	1.0	3.8	2.6	2.2	4.8	3.6	5.8	7.2
	7.5	45.2	46.2	47.6	50.2	48.4	1.0	1.4	2.6	-1.8	2.4	4.0	0.8	5.0	2.2	3.2
	8	45.8	49.0	48.2	51.2	47.8	3.2	-0.8	3.0	-3.4	2.4	2.2	-0.4	5.4	-1.2	2.0
	8.5	50.2	51.4	51.4	52.2	52.4	1.2	0.0	0.8	0.2	1.2	0.8	1.0	2.0	1.0	2.2
	9	47.8	49.0	48.3	52.3	51.3	1.3	-0.8	4.0	-1.0	0.5	3.3	3.0	4.5	2.3	3.5
	9.5	45.0	46.0	48.8	49.0	48.6	1.0	0.8	2.2	-0.4	1.8	3.0	1.8	4.0	2.6	3.6
	10	54.4	54.0	55.8	57.4	56.4	-0.4	1.8	1.8	-1.0	1.4	3.4	0.8	3.0	2.4	2.0
	10.5	51.5	52.8	53.3	56.3	54.8	1.3	0.5	3.0	-1.5	1.8	3.5	1.5	4.8	2.0	3.3
	11	50.8	52.8	53.2	57.8	55.0	1.8	0.6	4.4	-2.6	2.4	5.0	1.8	6.8	2.4	4.2
	11.5	50.0	49.3	52.0	51.7	51.5	-0.7	2.7	-0.3	-0.2	2.0	2.3	-0.5	1.7	2.2	1.5
	12	51.2	51.4	52.2	54.6	55.2	0.2	0.8	2.4	0.6	1.0	3.2	3.0	3.4	3.8	4.0
	12.5	53.2	52.6	54.4	55.8	58.4	-0.6	1.8	1.4	2.6	1.2	3.2	4.0	2.6	5.8	5.2
	13	47.8	48.2	48.6	54.2	53.0	0.4	0.4	5.6	-1.2	0.8	6.0	4.4	6.4	4.8	5.2
	13.5	46.6	49.0	50.4	52.8	57.8	2.4	1.4	2.4	5.0	3.8	3.8	7.4	6.2	8.8	11.2
	14	42.8	46.4	46.2	53.8	52.4	3.6	-0.2	7.6	-1.4	3.4	7.4	6.2	11.0	6.0	9.6
	14.5	45.0	48.8	48.2	49.8	50.8	3.8	-0.6	1.6	1.0	3.2	1.0	2.6	4.8	2.0	5.8
	15	47.4	48.6	48.4	54.0	54.0	1.2	-0.2	5.6	0.0	1.0	5.4	5.6	6.6	5.4	6.6
	15.5	47.0	49.2	48.8	53.8	52.2	2.2	-0.4	5.0	-1.6	1.8	4.6	3.4	6.8	3.0	5.2
	16	45.4	47.2	48.2	52.0	51.8	1.8	1.0	3.8	-0.2	2.8	4.8	3.6	6.6	4.6	6.4
	16.5	47.3	48.5	50.0	52.0	51.0	1.3	1.5	2.0	-1.0	2.8	3.5	1.0	4.8	2.5	3.8
	17	44.0	45.2	46.4	51.6	53.8	1.2	1.2	5.2	2.2	2.4	6.4	7.4	7.6	8.6	9.8
44044w	0	45.7	47.0	50.7	49.3	49.7	1.3	3.7	-1.3	0.3	5.0	2.3	-1.0	3.7	2.7	4.0
	0.5	42.0	43.8	50.0	51.0	51.3	1.8	6.3	1.0	0.3	8.0	7.3	1.3	9.0	7.6	9.3
	1	41.8	39.6	47.4	47.8	47.0	-2.2	7.8	0.4	-0.8	5.6	8.2	-0.4	6.0	7.4	5.2
	1.5	39.0	39.0	46.6	55.8	49.6	0.0	7.6	9.2	-6.2	7.6	16.8	3.0	16.8	10.6	10.6
	2	43.2	42.4	49.2	43.8	46.4	-0.8	6.8	-5.4	2.6	8.0	1.4	-2.8	0.6	4.0	3.2
	2.5	36.4	36.6	43.2	49.0	45.8	0.2	6.6	5.8	-3.2	6.8	12.4	2.6	12.6	9.2	9.4
	3	38.8	42.3	44.3	48.0	49.3	3.5	2.0	3.8	1.3	5.5	5.8	5.0	9.3	7.0	10.5
	3.5	43.0	47.2	51.2	50.6	51.4	4.2	4.0	-0.6	0.8	8.2	3.4	0.2	7.6	4.2	8.4
	4	41.0	39.0	46.0	48.0	51.8	-2.0	7.0	2.0	3.8	5.0	9.0	5.8	7.0	12.8	10.8
	4.5	43.8	42.6	49.2	52.2	53.4	-1.2	6.6	3.0	1.2	5.4	9.6	4.2	8.4	10.8	9.6
	5	41.2	41.0	45.0	48.6	47.2	-0.2	4.0	3.6	-1.4	3.8	7.6	2.2	7.4	6.2	6.0
	5.5	48.4	50.6	56.4	56.8	58.0	2.2	5.8	0.4	1.2	8.0	6.2	1.6	8.4	7.4	9.6
	6	38.4	42.4	46.2	52.0	50.4	4.0	3.8	5.8	-1.6	7.8	9.6	4.2	13.6	8.0	12.0
	6.5	49.8	53.6	58.2	61.2	59.2	3.8	4.6	3.0	-2.0	8.4	7.6	1.0	11.4	5.6	9.4

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	98	93-92	94-93	95-94	98-95	94-92	95-93	96-94	95-92	96-93	96-92
44044w	7	42.8	45.6	50.2	49.6	49.8	2.8	4.8	-0.6	0.0	7.4	4.0	-0.6	6.8	4.0	6.8
	7.5	47.8	48.0	51.4	51.8	50.6	0.2	3.4	0.2	-1.0	3.6	3.8	-0.8	3.8	2.6	2.8
	8	45.8	46.4	51.4	48.8	52.4	0.6	5.0	-2.6	3.6	5.6	2.4	1.0	3.0	6.0	6.6
	8.5	43.2	43.6	49.0	47.4	47.6	0.4	5.4	-1.6	0.2	5.8	3.8	-1.4	4.2	4.0	4.4
	9	45.3	46.8	49.8	50.8	54.7	1.5	3.0	1.0	3.9	4.5	4.0	4.9	5.5	7.9	9.4
	9.5	49.2	53.0	54.8	52.8	56.4	3.8	1.6	-1.8	3.6	5.4	-0.2	1.8	3.6	3.4	7.2
	10	51.4	52.6	53.2	58.5	55.8	1.2	0.6	5.3	-2.9	1.8	5.9	2.4	7.1	3.0	4.2
	10.5	58.0	56.3	57.8	56.0	56.5	-1.8	1.5	-1.8	0.5	-0.3	-0.3	-1.3	-2.0	0.3	-1.5
	11	51.2	50.0	55.2	55.8	55.8	-1.2	5.2	0.5	0.0	4.0	5.8	0.5	4.6	5.8	4.6
	11.5	53.3	54.7	55.3	55.7	53.7	1.3	0.7	0.3	-2.0	2.0	1.0	-1.7	2.3	-1.0	0.3
	12	53.2	54.4	56.2	58.4	56.2	1.2	1.8	2.2	-2.2	3.0	4.0	0.0	5.2	1.8	3.0
	12.5	52.6	56.8	53.6	54.4	57.8	4.2	-3.2	0.8	3.4	1.0	-2.4	4.2	1.8	1.0	5.2
	13	47.2	51.8	48.2	49.6	51.0	4.6	-3.6	1.4	1.4	1.0	-2.2	2.8	2.4	-0.8	3.8
	13.5	49.4	49.2	51.0	50.2	51.6	-0.2	1.8	-0.8	1.4	1.6	1.0	0.8	0.8	2.4	2.2
	14	45.2	47.8	47.8	52.8	54.6	2.4	0.2	5.0	1.8	2.6	5.2	6.8	7.6	7.0	9.4
	14.5	49.2	50.0	54.0	57.8	60.8	0.8	4.0	3.8	3.0	4.8	7.8	6.8	8.6	10.8	11.6
	15	51.8	57.0	59.8	63.0	71.4	5.2	2.8	3.2	8.4	8.0	6.0	11.6	11.2	14.4	19.6
	15.5	52.8	60.2	61.6	71.8	76.0	7.4	1.4	10.2	4.2	8.8	11.6	14.4	19.0	15.8	23.2
	16	51.0	53.4	58.6	56.2	81.8	2.4	5.2	-2.4	5.8	7.6	2.8	3.2	5.2	8.4	10.8
	16.5	49.8	50.5	53.5	60.5	66.8	0.8	3.0	7.0	6.3	3.8	10.0	13.3	10.8	16.3	17.0
	17	49.2	52.0	54.0	58.6	62.2	2.8	2.0	4.6	3.6	4.8	6.6	8.2	9.4	10.2	13.0
80023e	4	73.0	73.6	75.8	77.4	81.0	0.6	2.2	1.6	3.6	2.8	3.8	5.2	4.4	7.4	8.0
	4.5	69.2	72.0	74.0	75.6	77.4	2.8	2.0	1.6	1.8	4.8	3.6	3.4	6.4	5.4	8.2
	5	68.0	72.4	75.2	76.2	78.0	4.4	2.8	1.0	1.8	7.2	3.8	2.8	8.2	5.6	10.0
	5.5	62.6	65.2	68.0	69.6	71.2	2.6	2.8	1.6	1.6	5.4	4.4	3.2	7.0	6.0	8.6
	8	71.6	76.6	79.8	78.4	81.8	5.0	3.2	-1.4	3.4	8.2	1.8	2.0	6.8	5.2	10.2
	6.5	67.6	71.2	72.6	73.4	76.8	3.6	1.4	0.8	3.4	5.0	2.2	4.2	5.8	5.6	9.2
	7	69.8	75.4	76.0	76.5	80.4	5.6	0.6	0.5	3.9	6.2	1.1	4.4	6.7	5.0	10.8
	7.5	66.8	71.8	74.0	73.6	78.2	5.0	2.2	-0.4	4.6	7.2	1.8	4.2	6.8	6.4	11.4
	8	63.6	68.2	69.2	71.2	73.6	4.6	1.0	2.0	2.4	5.6	3.0	4.4	7.6	5.4	10.0
	8.5	70.8	75.6	77.4	77.4	79.4	4.8	1.8	0.0	2.0	8.6	1.8	2.0	6.6	3.8	8.6
	9	72.8	75.8	77.6	78.6	81.2	3.0	1.8	1.0	2.8	4.8	2.8	3.6	5.8	5.4	8.4
	9.5	74.0	76.8	77.6	76.8	79.0	2.8	0.8	-0.8	2.2	3.6	0.0	1.4	2.8	2.2	5.0
	10	66.6	71.4	73.6	75.0	77.6	4.8	2.2	1.4	2.6	7.0	3.6	4.0	8.4	6.2	11.0
	10.5	69.0	70.8	73.0	73.0	76.8	1.8	2.2	0.0	3.8	4.0	2.2	3.8	4.0	6.0	7.8
	11	66.2	67.8	71.4	74.6	74.2	1.8	3.6	3.2	-0.4	5.2	6.8	2.8	8.4	6.4	8.0
	11.5	57.4	61.4	82.8	65.2	69.0	4.0	1.4	2.4	3.8	5.4	3.8	6.2	7.8	7.6	11.6
	12	61.8	67.2	68.2	71.0	73.2	5.4	1.0	2.8	2.2	6.4	3.8	5.0	9.2	6.0	11.4
	12.5	61.4	67.4	68.4	89.2	73.6	6.0	1.0	0.8	4.4	7.0	1.8	5.2	7.8	6.2	12.2
	13	58.6	68.5	69.2	70.6	75.2	9.9	0.7	1.4	4.6	10.6	2.1	6.0	12.0	6.7	16.6
58034n	10	48.6	47.2	48.0		49.8	0.6	0.8			1.4		1.8		2.6	3.2
	10.5	46.0	47.2	48.6	51.8	54.6	1.2	1.4	3.2	2.8	2.6	4.6	6.0	5.8	7.4	8.6
	11	47.4	47.4	48.2	50.8	52.2	0.0	0.8	2.6	1.4	0.8	3.4	4.0	3.4	4.8	4.8
	11.5	45.4	48.8	47.2	49.8	51.8	1.4	0.4	2.4	2.0	1.8	2.8	4.4	4.2	4.8	6.2
	12	45.0	46.0	46.0	48.6	49.6	1.0	0.0	2.6	1.0	1.0	2.6	3.6	3.6	3.6	4.6

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	98	93-92	94-93	95-94	98-95	94-92	95-93	98-94	95-92	96-93	96-92
58034n	12.5	48.2	49.0	49.8	50.6	52.2	0.8	0.8	0.8	1.6	1.6	1.6	2.4	2.4	3.2	4.0
	13	53.5	53.4	55.8	57.5	59.5	-0.1	2.4	1.8	2.0	2.3	4.1	3.8	4.0	6.1	6.0
	13.5	55.4	54.8	57.0	54.8	56.3	-0.8	2.3	-2.3	1.5	1.8	0.0	-0.8	-0.6	1.5	0.9
	14	49.2	51.6	54.2	54.2	57.8	2.4	2.6	0.0	3.6	5.0	2.6	3.6	5.0	6.2	6.6
	14.5	53.4	56.2	56.2	60.6	62.4	2.8	0.0	4.4	1.6	2.8	4.4	6.2	7.2	6.2	9.0
	15	66.0	65.4	67.2	88.8	73.4	-0.8	1.8	1.6	4.6	1.2	3.4	6.2	2.8	8.0	7.4
	15.5	65.5	64.8	67.3	64.8	67.7	-0.8	2.5	-2.5	2.9	1.8	0.0	0.4	-0.8	2.9	2.2
	16	55.4	57.6	64.8	63.8	70.8	2.2	7.0	-0.8	7.0	9.2	6.2	6.2	8.4	13.2	15.4
58034s	10	43.6	45.0	46.4	N.A.	45.4	1.4	1.4	N.A.	N.A.	2.8	N.A.	-1.0	N.A.	0.4	1.8
	10.5	43.4	44.0	43.4	48.0	48.8	0.6	-0.6	4.8	0.8	0.0	4.0	5.4	4.6	4.8	5.4
	11	45.8	46.6	46.2	50.8	49.4	0.8	-0.4	4.6	-1.4	0.4	4.2	3.2	5.0	2.8	3.6
	11.5	41.4	40.2	41.2	43.4	44.2	-1.2	1.0	2.2	0.6	-0.2	3.2	3.0	2.0	4.0	2.8
	12	46.8	46.8	46.6	48.4	46.0	0.0	-0.2	1.6	-0.4	-0.2	1.6	1.4	1.6	1.2	1.2
	12.5	44.6	44.6	44.2	48.0	47.4	0.0	-0.4	1.8	1.4	-0.4	1.4	3.2	1.4	2.8	2.8
	13	50.0	50.5	50.5	52.3	51.5	0.5	0.0	1.8	-0.8	0.5	1.8	1.0	2.3	1.0	1.5
	13.5	46.8	46.2	46.2	44.3	44.0	-0.6	0.0	-2.0	-0.3	-0.8	-2.0	-2.2	-2.6	-2.2	-2.8
	14	42.0	42.4	42.2	45.4	45.4	0.4	-0.2	3.2	0.0	0.2	3.0	3.2	3.4	3.0	3.4
	14.5	41.6	44.2	43.6	46.6	45.2	2.6	-0.8	3.0	-1.4	2.0	2.4	1.6	5.0	1.0	3.6
	15	46.0	46.6	48.4	48.4	48.6	0.6	1.8	0.0	0.2	2.4	1.8	0.2	2.4	2.0	2.6
	15.5	53.8	54.3	55.0	49.3	49.7	0.5	0.8	-5.7	0.3	1.3	-4.9	-5.3	-4.4	-4.6	-4.1
	16	47.8	49.0	49.2	50.8	50.8	1.2	0.2	1.6	0.0	1.4	1.8	1.6	3.0	1.8	3.0
77024e	0	52.0	54.6	55.8	65.0	66.6	2.6	1.2	9.2	1.6	3.8	10.4	10.8	13.0	12.0	14.6
	0.5	44.6	47.0	51.4	56.8	58.2	2.4	4.4	5.4	1.4	8.8	9.8	6.8	12.2	11.2	13.6
	1	43.8	45.6	50.0	54.8	55.8	1.8	4.4	4.8	1.0	6.2	9.2	5.8	11.0	10.2	12.0
	1.5	50.8	52.2	59.2	62.6	66.2	1.4	7.0	3.4	3.6	8.4	10.4	7.0	11.8	14.0	15.4
	2	41.8	42.8	46.0	50.2	51.0	1.0	3.2	4.2	0.8	4.2	7.4	5.0	8.4	8.2	9.2
	2.5	40.4	40.6	42.6	48.4	47.8	0.2	2.0	5.8	-0.6	2.2	7.8	5.2	8.0	7.2	7.4
	3	41.2	42.0	43.2	49.8	50.8	0.8	1.2	6.4	1.2	2.0	7.6	7.6	8.4	8.8	9.6
	3.5	47.6	52.6	55.4	60.2	63.8	5.0	2.8	4.8	3.6	7.8	7.6	8.4	12.6	11.2	16.2
	4	49.8	54.2	56.4	61.6	65.4	4.4	2.2	5.2	3.6	6.6	7.4	9.0	11.8	11.2	15.6
	4.5	47.0	55.8	56.4	63.2	72.0	8.8	0.6	6.8	6.6	9.4	7.4	15.8	16.2	18.2	25.0
	5	53.0	61.8	65.8	69.6	72.8	8.8	3.8	4.0	3.2	12.6	7.8	7.2	16.6	11.0	19.8
	5.5	45.3	47.3	49.0	52.5	51.5	2.0	1.8	3.5	-1.0	3.8	5.3	2.5	7.3	4.3	6.3
	6	49.0	50.8	50.6	53.8	52.6	1.8	-0.2	3.2	-1.2	1.6	3.0	2.0	4.8	1.8	3.6
	6.5	55.0	56.6	59.2	59.2	57.6	1.6	2.6	0.0	-1.6	4.2	2.6	-1.6	4.2	1.0	2.6
	7	49.6	51.0	52.0	54.8	52.0	1.4	1.0	2.8	-2.8	2.4	3.8	0.0	5.2	1.0	2.4
	7.5	51.2	51.6	52.6	54.0	53.8	0.4	1.0	1.4	-0.2	1.4	2.4	1.2	2.8	2.2	2.6
	8	50.8	51.0	51.6	53.6	52.8	0.2	0.6	2.0	-0.8	0.8	2.6	1.2	2.8	1.8	2.0
	8.5	51.0	56.2	51.8	56.6	55.2	5.2	-4.6	5.0	-1.4	0.6	0.4	3.8	5.6	-1.0	4.2
	9	47.6	48.2	49.0	54.0	50.6	0.6	0.8	5.0	-3.4	1.4	5.8	1.6	6.4	2.4	3.0
	9.5	51.2	52.6	52.8	58.0	55.0	1.4	0.2	5.2	-3.0	1.6	5.4	2.2	6.6	2.4	3.8
	10	52.0	54.6	54.2	58.2	56.0	2.6	-0.4	4.0	-2.2	2.2	3.6	1.8	6.2	1.4	4.0
	10.5	49.2	50.6	50.8	58.2	54.0	1.4	0.2	7.4	-4.2	1.6	7.6	3.2	9.0	3.4	4.8
	11	51.4	52.8	52.8	56.0	53.8	1.4	0.0	3.2	-2.4	1.4	3.2	0.6	4.6	0.8	2.2

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	96	93-92	94-93	95-94	96-95	94-92	95-93	96-94	95-92	96-93	96-92
77024w	0	49.4	52.6	58.0	61.4	67.8	3.2	5.4	3.4	6.4	8.6	8.8	9.8	12.0	15.2	18.4
	0.5	50.2	51.4	53.4	59.4	60.2	1.2	2.0	8.0	0.8	3.2	8.0	6.8	9.2	8.8	10.0
	1	40.0	43.2	48.0	51.8	52.2	3.2	4.8	3.8	0.4	8.0	8.6	4.2	11.8	9.0	12.2
	1.5	42.8	43.6	45.0	50.2	48.2	1.0	1.4	5.2	-2.0	2.4	6.6	3.2	7.6	4.8	5.6
	2	41.8	45.0	44.4	51.2	51.2	3.2	-0.6	6.8	0.0	2.6	6.2	6.8	9.4	6.2	9.4
	2.5	44.2	46.8	48.8	55.4	54.4	2.6	2.0	6.6	-1.0	4.8	8.6	5.8	11.2	7.8	10.2
	3	47.6	54.0	55.8	63.8	69.2	6.4	1.8	8.0	5.4	8.2	9.8	13.4	16.2	15.2	21.6
	3.5	43.6	44.6	46.2	52.2	51.6	1.0	1.6	6.0	-0.6	2.6	7.6	5.4	8.6	7.0	8.0
	4	45.6	51.0	50.2	57.6	57.2	5.4	-0.8	7.4	-0.4	4.6	6.8	7.0	12.0	6.2	11.6
	4.5	41.8	45.4	43.4	49.8	50.6	3.8	-2.0	6.4	0.8	1.6	4.4	7.2	8.0	5.2	8.8
	5	44.8	44.2	47.2	52.2	52.8	-0.6	3.0	5.0	0.6	2.4	8.0	5.8	7.4	8.6	8.0
	5.5	43.3	43.5	46.3	51.7	50.3	0.3	2.8	5.4	-1.4	3.0	8.2	4.0	8.4	6.8	7.0
	6	46.6	45.6	47.4	49.2	49.6	-1.0	1.8	1.8	0.4	0.8	3.6	2.2	2.6	4.0	3.0
	6.5	47.8	48.6	48.4	52.8	51.4	0.8	-0.2	4.4	-1.4	0.8	4.2	3.0	5.0	2.8	3.6
	7	51.6	51.0	51.8	55.0	53.8	-0.8	0.8	3.2	-1.2	0.2	4.0	2.0	3.4	2.8	2.2
	7.5	47.8	48.4	49.2	51.8	50.8	0.8	0.8	2.6	-1.0	1.6	3.4	1.6	4.2	2.4	3.2
	8	46.0	48.4	48.2	49.8	49.6	2.4	-0.2	1.6	-0.2	2.2	1.4	1.4	3.8	1.2	3.6
	8.5	49.8	53.2	52.2	54.6	52.2	3.4	-1.0	2.4	-2.4	2.4	1.4	0.0	4.8	-1.0	2.4
	9	47.0	50.0	51.2	53.2	50.8	3.0	1.2	2.0	-2.4	4.2	3.2	-0.4	6.2	0.8	3.8
	9.5	49.2	53.2	54.4	53.2	53.2	4.0	1.2	-1.2	0.0	5.2	0.0	-1.2	4.0	0.0	4.0
	10	47.0	50.0	50.8	51.8	49.6	3.0	0.8	1.0	-2.2	3.8	1.8	-1.2	4.8	-0.4	2.6
	10.5	48.0	47.6	49.2	51.0	49.4	-0.4	1.6	1.8	-1.6	1.2	3.4	0.2	3.0	1.8	1.4
	11	51.4	55.0	57.6	58.2	53.8	3.6	2.6	0.6	-4.6	6.2	3.2	-4.0	6.8	-1.4	2.2
82191n1	0	76.0	78.3	88.2	82.4	89.6	2.3	9.9	-5.8	7.2	12.2	4.1	1.4	6.4	11.3	13.6
	0.5	63.6	64.8	69.8	71.2	75.4	1.2	4.8	1.6	4.2	6.0	6.4	5.8	7.6	10.6	11.8
	1	54.0	55.6	61.4	62.0	63.4	1.6	5.8	0.6	1.4	7.4	6.4	2.0	8.0	7.8	9.4
	1.5	58.8	63.0	65.8	67.0	70.6	4.2	2.8	1.2	3.6	7.0	4.0	4.8	8.2	7.6	11.8
	2	55.2	59.8	61.8	64.8	70.6	4.6	2.0	3.0	5.8	6.6	5.0	8.8	9.6	10.8	15.4
	2.5	48.0	48.4	55.6	57.2	61.6	0.4	7.2	1.6	4.4	7.6	8.8	8.0	9.2	13.2	13.6
	3	55.6	60.0	66.0	69.8	74.6	4.4	6.0	3.8	4.8	10.4	9.8	8.6	14.2	14.6	19.0
	3.5	59.0	61.0	68.5	70.0	74.3	2.0	7.5	1.5	4.3	9.5	9.0	5.8	11.0	13.3	15.3
	4	60.3	71.0	76.4	74.3	81.3	10.8	5.4	-2.2	7.0	16.2	3.3	4.8	14.0	10.3	21.0
	4.5	63.8	61.2	68.4	72.2	77.8	-2.6	7.2	3.8	5.6	4.6	11.0	9.4	8.4	16.6	14.0
	5	56.6	62.2	64.2	68.6	70.0	5.6	2.0	4.4	1.4	7.6	6.4	5.8	12.0	7.8	13.4
	5.5	46.0	48.4	48.4	51.0	54.0	0.4	2.0	2.6	3.0	2.4	4.6	5.6	5.0	7.6	8.0
	6	48.4	47.4	55.4	59.4	60.8	-1.0	8.0	4.0	1.4	7.0	12.0	5.4	11.0	13.4	12.4
50061e	0	60.8	43.8	61.8	83.6	63.6	-17.0	18.0	1.8	0.0	1.0	19.8	1.8	2.8	19.8	2.8
	0.5	58.8	47.0	67.0	62.8	62.8	-11.8	20.0	-4.2	0.0	8.2	15.8	-4.2	4.0	15.8	4.0
	1	55.0	48.6	54.8	56.4	56.4	-6.4	6.2	1.6	0.0	-0.2	7.8	1.6	1.4	7.8	1.4
	1.5	60.4	56.4	58.4	57.6	57.8	-4.0	2.0	-0.8	0.0	-2.0	1.2	-0.8	-2.8	1.2	-2.8
	2	61.2	62.4	61.8	61.6	61.6	1.2	-0.6	-0.2	0.0	0.6	-0.8	-0.2	0.4	-0.8	0.4
	2.5	68.8	66.0	65.0	61.6	61.6	-2.8	-1.0	-3.4	0.0	-3.8	-4.4	-3.4	-7.2	-4.4	-7.2
	3	52.0	51.2	62.0	52.8	52.8	-0.8	10.8	-9.2	0.0	10.0	1.6	-9.2	0.8	1.6	0.8
	3.5	53.2	51.8	55.0	58.2	58.2	-1.4	3.2	3.2	0.0	1.8	6.4	3.2	5.0	6.4	5.0
	4	52.2	51.0	52.8	54.4	54.4	-1.2	1.8	1.6	0.0	0.6	3.4	1.6	2.2	3.4	2.2
	4.5	54.8	54.6	54.0	54.2	54.2	-0.2	-0.6	0.2	0.0	-0.8	-0.4	0.2	-0.6	-0.4	-0.6

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	96	93-92	94-93	95-94	96-95	94-92	95-93	96-94	95-92	96-93	96-92
50061e	5	53.2	54.0	54.2	53.4	53.4	0.8	0.2	-0.8	0.0	1.0	-0.6	-0.8	0.2	-0.6	0.2
	5.5	55.8	54.8	55.4	54.2	54.2	-1.0	0.6	-1.2	0.0	-0.4	-0.6	-1.2	-1.6	-0.6	-1.8
82122e	2.5	55.8	48.4	78.6	51.0	64.8	-7.4	30.2	-27.8	13.8	22.8	2.6	-13.6	-4.8	16.4	9.0
	3	53.2	44.6	64.4	47.2	57.6	-8.6	19.8	-17.2	10.4	11.2	2.6	-6.6	-6.0	13.0	4.4
	3.5	51.8	62.8	62.2	55.2	59.8	11.0	-0.8	-7.0	4.6	10.4	-7.6	-2.4	3.4	-3.0	8.0
	4	48.0	46.2	55.6	50.0	50.0	-1.8	9.4	-5.8	0.0	7.8	3.8	-5.6	2.0	3.8	2.0
	4.5	51.8	55.0	59.2	54.0	56.4	3.2	4.2	-5.2	2.4	7.4	-1.0	-2.8	2.2	1.4	4.6
	5	54.2	55.2	65.0	57.8	63.0	1.0	9.8	-7.4	5.4	10.8	2.4	-2.0	3.4	7.8	8.8
	5.5	50.8	52.8	80.2	52.8	50.0	2.0	7.4	-7.6	-2.6	9.4	-0.2	-10.2	1.8	-2.8	-0.6
	6	48.2	49.8	51.4	50.8	50.4	1.8	1.8	-0.8	-0.2	3.2	0.8	-1.0	2.4	0.6	2.2
	6.5	52.0	58.2	55.8	80.4	51.8	6.2	-2.6	4.8	-8.8	3.6	2.2	-4.0	8.4	-6.6	-0.4
	7	53.2	52.0	56.8	59.8	54.0	-1.2	4.8	3.0	-5.8	3.6	7.8	-2.8	8.8	2.0	0.8
	7.5	52.8	52.2	55.4	54.8	55.6	-0.6	3.2	-0.8	1.0	2.6	2.4	0.2	1.8	3.4	2.8
	8	47.2	38.6	50.2	48.4	47.2	-8.6	11.8	-1.8	-1.2	3.0	9.8	-3.0	1.2	8.6	0.0
	8.5	66.4	60.2	75.8	65.8	67.6	-6.2	15.8	-10.0	1.8	9.4	5.6	-8.2	-0.6	7.4	1.2
	9	64.5	54.3	63.8	64.0	67.3	-10.3	9.5	0.3	3.3	-0.8	9.8	3.6	-0.5	13.1	2.8
	9.5	57.6	55.2	58.0	60.4	57.8	-2.4	2.8	2.4	-2.8	0.4	5.2	-0.2	2.8	2.6	0.2
	10	51.8	55.8	61.2	58.4	55.6	4.0	5.4	-2.8	-2.8	9.4	2.6	-5.6	6.6	-0.2	3.8
	10.5	59.0	58.4	69.4	59.0	61.8	-0.6	11.0	-10.4	2.8	10.4	0.6	-7.6	0.0	3.4	2.8
	11	56.0	58.2	64.8	57.8	58.2	2.2	6.4	-6.8	0.4	8.8	-0.4	-6.4	1.8	0.0	2.2
	11.5	58.0	62.2	66.4	60.2	62.0	4.2	4.2	-6.2	1.8	8.4	-2.0	-4.4	2.2	-0.2	4.0
82122w	2.5	47.6	57.2	53.6	57.2	59.0	9.6	-3.6	3.6	1.8	6.0	0.0	5.4	9.6	1.8	11.4
	3	51.8	65.8	58.4	65.8	66.0	14.2	-7.4	7.4	0.2	6.8	0.0	7.6	14.2	0.2	14.4
	3.5	68.4	75.8	60.2	75.8	77.6	7.4	-15.6	15.6	1.8	-8.2	0.0	17.4	7.4	1.8	9.2
	4	58.8	60.0	64.2	60.0	68.2	1.2	4.2	-4.2	8.2	5.4	0.0	4.0	1.2	8.2	9.4
	4.5	56.2	63.0	65.0	83.0	64.2	6.8	2.0	-2.0	1.2	8.8	0.0	-0.8	6.8	1.2	8.0
	5	55.4	52.0	62.4	52.0	52.4	-3.4	10.4	-10.4	0.4	7.0	0.0	-10.0	-3.4	0.4	-3.0
	5.5	49.0	49.2	49.6	49.2	47.2	0.2	0.4	-0.4	-2.0	0.6	0.0	-2.4	0.2	-2.0	-1.8
	6	43.6	45.6	44.4	45.8	49.4	2.0	-1.2	1.2	3.8	0.8	0.0	5.0	2.0	3.8	5.8
	6.5	54.2	53.0	52.8	53.0	57.2	-1.2	-0.2	0.2	4.2	-1.4	0.0	4.4	-1.2	4.2	3.0
	7	55.4	57.4	52.8	57.4	57.6	2.0	-4.6	4.6	0.2	-2.6	0.0	4.8	2.0	0.2	2.2
	7.5	57.4	55.0	58.2	55.0	54.4	-2.4	3.2	-3.2	-0.6	0.8	0.0	-3.8	-2.4	-0.6	-3.0
	8	52.6	53.8	42.4	53.8	50.2	1.2	-11.4	11.4	-3.6	-10.2	0.0	7.8	1.2	-3.6	-2.4
	8.5	63.6	71.2	58.6	71.2	62.6	7.8	-12.6	12.6	-8.6	-5.0	0.0	4.0	7.6	-8.6	-1.0
	9	78.0	72.3	63.7	72.3	72.3	-5.8	-8.6	8.6	0.0	-14.3	0.0	8.6	-5.8	0.0	-5.8
	9.5	59.6	69.6	62.6	69.6	70.2	10.0	-7.0	7.0	0.6	3.0	0.0	7.6	10.0	0.6	10.6
	10	63.0	58.2	60.4	58.2	70.8	-4.8	2.2	-2.2	12.6	-2.6	0.0	10.4	-4.8	12.8	7.8
	10.5	58.2	60.0	63.0	60.0	65.8	1.8	3.0	-3.0	5.8	4.6	0.0	2.8	1.8	5.8	7.6
	11	62.2	62.8	63.2	62.8	70.8	0.6	0.4	-0.4	7.8	1.0	0.0	7.4	0.6	7.8	8.4
	11.5	54.5	52.5	58.5	52.5	53.0	-2.0	6.0	-6.0	0.5	4.0	0.0	-5.5	-2.0	0.5	-1.5
18024e	1.5	52.1	48.2	46.6	56.5	N.A.	-3.9	-1.6	9.9	N.A.	-5.5	8.3	N.A.	4.4	N.A.	N.A.
	2.5	52.5	56.6	56.4	53.8	N.A.	4.1	-0.2	-2.6	N.A.	3.9	-2.8	N.A.	1.3	N.A.	N.A.
	3.5	50.7	53.0	52.2	53.0	N.A.	2.3	-0.8	0.8	N.A.	1.5	0.0	N.A.	2.3	N.A.	N.A.
	4.5	52.8	53.0	53.6	56.5	N.A.	0.4	0.8	2.7	N.A.	1.2	3.5	N.A.	3.9	N.A.	N.A.
	5.5	53.3	54.0	55.8	57.9	N.A.	0.7	1.8	2.1	N.A.	2.5	3.9	N.A.	4.6	N.A.	N.A.

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	96	93-92	94-93	95-94	96-95	94-92	95-93	96-94	95-92	96-93	96-92
	6.5	55.2	58.0	63.8	66.6	N.A.	2.8	5.8	2.8	N.A.	8.6	8.6	N.A.	11.4	N.A.	N.A.
18024w	0	45.8	50.2	53.4	50.5	N.A.	4.5	3.2	-2.9	N.A.	7.7	0.3	N.A.	4.8	N.A.	N.A.
	0.5	55.8	50.8	56.4	59.0	N.A.	-5.0	5.6	2.6	N.A.	0.6	8.2	N.A.	3.2	N.A.	N.A.
	1	43.8	42.4	46.8	51.5	N.A.	-1.4	4.4	4.7	N.A.	3.1	9.1	N.A.	7.8	N.A.	N.A.
	1.5	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
	2	59.8	58.8	59.2	65.8	N.A.	-1.0	0.4	8.4	N.A.	-0.6	6.8	N.A.	5.6	N.A.	N.A.
	2.5	48.2	46.6	53.4	54.6	N.A.	-1.6	6.8	1.4	N.A.	5.2	8.2	N.A.	6.8	N.A.	N.A.
	3	51.6	52.8	53.8	55.2	N.A.	1.2	1.0	1.4	N.A.	2.2	2.4	N.A.	3.6	N.A.	N.A.
	3.5	51.4	52.2	51.8	55.8	N.A.	0.8	-0.4	4.0	N.A.	0.4	3.6	N.A.	4.4	N.A.	N.A.
	4	47.0	48.4	50.4	56.6	N.A.	1.4	2.0	8.2	N.A.	3.4	8.2	N.A.	9.6	N.A.	N.A.
	4.5	48.2	49.4	49.0	51.2	N.A.	1.2	-0.4	2.2	N.A.	0.8	1.8	N.A.	3.0	N.A.	N.A.
	5	50.8	55.0	54.4	58.2	N.A.	4.2	-0.8	1.8	N.A.	3.6	1.2	N.A.	5.4	N.A.	N.A.
	5.5	52.6	55.0	54.8	59.2	N.A.	2.4	-0.2	4.4	N.A.	2.2	4.2	N.A.	6.6	N.A.	N.A.
	8	52.2	52.4	52.8	57.4	N.A.	0.2	0.4	4.6	N.A.	0.6	5.0	N.A.	5.2	N.A.	N.A.
	6.5	46.8	55.4	56.2	53.8	N.A.	8.7	0.8	-2.5	N.A.	7.5	-1.7	N.A.	5.0	N.A.	N.A.
	7	54.2	55.0	54.6	58.0	N.A.	0.8	-0.4	3.4	N.A.	0.4	3.0	N.A.	3.8	N.A.	N.A.
65041n	10.5	64.0	63.8	65.0	66.8	70.4	-0.2	1.2	1.8	3.6	1.0	3.0	5.4	2.8	6.6	6.4
	11	53.8	53.3	55.0	56.8	60.5	-0.5	1.8	1.8	3.8	1.3	3.5	5.5	3.0	7.3	6.8
	11.5	58.2	58.2	58.2	60.0	63.8	0.0	0.0	1.8	3.8	0.0	1.8	5.6	1.8	5.6	5.6
	12	56.8	56.0	56.6	58.4	61.6	-0.8	0.6	1.8	3.2	-0.2	2.4	5.0	1.6	5.6	4.8
	12.5	54.0	53.2	53.2	54.0	59.2	-0.8	0.0	0.8	5.2	-0.8	0.8	6.0	0.0	6.0	5.2
	13	47.2	47.4	46.0	48.6	50.0	0.2	-1.4	2.6	1.4	-1.2	1.2	4.0	1.4	2.6	2.8
	13.5	53.0	52.0	52.2	55.6	55.4	-1.0	0.2	3.4	-0.2	-0.8	3.6	3.2	2.6	3.4	2.4
	14	52.4	51.2	51.0	53.8	54.6	-1.2	-0.2	2.8	0.8	-1.4	2.6	3.6	1.4	3.4	2.2
	14.5	52.0	51.2	51.2	53.2	54.6	-0.8	0.0	2.0	1.4	-0.6	2.0	3.4	1.2	3.4	2.6
	15	57.8	52.7	58.8	59.3	62.3	-5.0	6.0	0.5	3.0	1.0	6.5	3.5	1.5	9.5	4.5
65041s	10.5	61.4	65.0	63.4	63.0	67.6	3.6	-1.6	-0.4	4.6	2.0	-2.0	4.2	1.6	2.6	6.2
	11	60.3	62.5	56.5	60.5	63.0	2.3	-6.0	4.0	2.5	-3.8	-2.0	6.5	0.3	0.5	2.8
	11.5	82.2	60.4	59.6	61.0	64.0	-1.8	-0.8	1.4	3.0	-2.8	0.6	4.4	-1.2	3.6	1.8
	12	52.6	53.4	55.0	53.4	54.4	0.8	1.6	-1.6	1.0	2.4	0.0	-0.6	0.8	1.0	1.8
	12.5	50.4	52.8	50.2	51.8	53.0	2.4	-2.6	1.8	1.2	-0.2	-1.0	2.8	1.4	0.2	2.6
	13	52.4	52.6	51.2	51.6	55.2	0.2	-1.4	0.4	3.8	-1.2	-1.0	4.0	-0.8	2.6	2.8
	13.5	53.0	53.4	53.8	56.2	58.4	0.4	0.4	2.4	2.2	0.8	2.8	4.6	3.2	5.0	5.4
	14	49.2	50.2	49.2	50.2	52.8	1.0	-1.0	1.0	2.6	0.0	0.0	3.6	1.0	2.6	3.6
	14.5	48.8	50.2	49.6	51.2	53.0	1.5	-0.8	1.6	1.6	0.9	1.0	3.4	2.5	2.8	4.3
	15	53.7	51.3	52.7	53.0	59.0	-2.3	1.3	0.3	6.0	-1.0	1.7	6.3	-0.7	7.7	5.3
41133n	0	N.A.	51.0	48.2	50.6	54.0	N.A.	-2.8	2.4	3.4	N.A.	-0.4	5.8	N.A.	3.0	N.A.
	0.5	N.A.	48.4	50.0	55.6	57.4	N.A.	1.6	5.6	1.8	N.A.	7.2	7.4	N.A.	9.0	N.A.
	1	N.A.	49.6	49.2	52.2	55.8	N.A.	-0.4	3.0	3.6	N.A.	2.6	6.6	N.A.	6.2	N.A.
	1.5	N.A.	46.4	53.0	53.2	59.6	N.A.	4.6	0.2	6.6	N.A.	4.8	6.8	N.A.	11.4	N.A.
	2	N.A.	46.0	51.2	49.0	53.6	N.A.	5.2	-2.2	4.8	N.A.	3.0	2.6	N.A.	7.8	N.A.
	2.5	N.A.	44.8	44.8	44.4	49.8	N.A.	0.0	-0.4	5.4	N.A.	-0.4	5.0	N.A.	5.0	N.A.
	3	N.A.	59.6	62.2	61.4	63.4	N.A.	2.6	-0.8	2.0	N.A.	1.8	1.2	N.A.	3.8	N.A.
	3.5	N.A.	62.3	65.8	66.6	69.7	N.A.	3.6	0.8	3.1	N.A.	4.3	3.9	N.A.	7.4	N.A.
	4	N.A.	46.8	51.2	51.4	56.2	N.A.	4.4	0.2	4.8	N.A.	4.6	5.0	N.A.	9.4	N.A.

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	96	93-92	94-93	95-94	96-95	94-92	95-93	96-94	95-92	96-93	96-92
	4.5	N.A.	44.2	42.2	44.2	47.4	N.A.	-2.0	2.0	3.2	N.A.	0.0	5.2	N.A.	3.2	N.A.
	5	N.A.	40.2	40.2	45.4	48.4	N.A.	0.0	5.2	1.0	N.A.	5.2	6.2	N.A.	6.2	N.A.
	5.5	N.A.	40.0	45.6	47.6	47.5	N.A.	5.6	2.0	-0.1	N.A.	7.6	1.9	N.A.	7.5	N.A.
	6	N.A.	51.8	48.2	48.2	53.3	N.A.	-3.6	0.0	5.1	N.A.	-3.6	5.1	N.A.	1.5	N.A.
	6.5	N.A.	46.0	44.0	45.6	48.8	N.A.	-2.0	1.6	3.2	N.A.	-0.4	4.6	N.A.	2.8	N.A.
	7	N.A.	46.4	44.0	46.4	51.0	N.A.	-2.4	2.4	4.6	N.A.	0.0	7.0	N.A.	4.6	N.A.
	7.5	N.A.	39.6	40.0	47.0	52.0	N.A.	0.4	7.0	5.0	N.A.	7.4	12.0	N.A.	12.4	N.A.
	8	N.A.	46.2	46.0	47.6	52.0	N.A.	-0.2	1.6	4.4	N.A.	1.4	6.0	N.A.	5.8	N.A.
41133s	0	N.A.	47.2	47.8	46.0	56.2	N.A.	0.6	-1.8	10.2	N.A.	-1.2	8.4	N.A.	9.0	N.A.
	0.5	N.A.	47.2	47.6	49.6	53.6	N.A.	0.4	2.0	4.0	N.A.	2.4	6.0	N.A.	6.4	N.A.
	1	N.A.	52.6	50.8	51.8	56.0	N.A.	-1.8	1.0	4.2	N.A.	-0.8	5.2	N.A.	3.4	N.A.
	1.5	N.A.	51.0	48.0	49.6	52.2	N.A.	-3.0	1.6	2.6	N.A.	-1.4	4.2	N.A.	1.2	N.A.
	2	N.A.	42.8	41.6	45.4	52.4	N.A.	-1.2	3.8	7.0	N.A.	2.6	10.8	N.A.	9.6	N.A.
	2.5	N.A.	51.4	50.0	53.4	50.6	N.A.	-1.4	3.4	-2.8	N.A.	2.0	0.6	N.A.	-0.8	N.A.
	3	N.A.	57.6	58.2	58.4	60.4	N.A.	0.6	0.2	2.0	N.A.	0.8	2.2	N.A.	2.8	N.A.
	3.5	N.A.	60.5	68.0	65.8	67.0	N.A.	7.5	-2.2	1.2	N.A.	5.3	-1.0	N.A.	6.5	N.A.
	4	N.A.	55.2	57.2	57.2	62.8	N.A.	2.0	0.0	5.6	N.A.	2.0	5.6	N.A.	7.6	N.A.
	4.5	N.A.	42.4	42.8	43.6	48.6	N.A.	0.4	0.8	5.0	N.A.	1.2	5.8	N.A.	6.2	N.A.
	5	N.A.	41.0	41.8	44.0	49.0	N.A.	0.8	2.2	5.0	N.A.	3.0	7.2	N.A.	8.0	N.A.
	5.5	N.A.	47.8	46.6	47.4	53.4	N.A.	-1.2	0.8	6.0	N.A.	-0.4	6.8	N.A.	5.6	N.A.
	6	N.A.	41.3	49.4	48.4	52.5	N.A.	8.2	-1.0	4.1	N.A.	7.2	3.1	N.A.	11.3	N.A.
	6.5	N.A.	33.8	32.2	34.0	38.0	N.A.	-1.6	1.8	4.0	N.A.	0.2	5.8	N.A.	4.2	N.A.
	7	N.A.	48.2	44.6	44.2	47.0	N.A.	-3.6	-0.4	2.8	N.A.	-4.0	2.4	N.A.	-1.2	N.A.
	7.5	N.A.	43.2	42.4	49.0	50.0	N.A.	-0.8	6.6	1.0	N.A.	5.8	7.6	N.A.	6.8	N.A.
	8	N.A.	49.6	49.4	59.2	62.0	N.A.	-0.2	9.8	2.8	N.A.	9.6	12.6	N.A.	12.4	N.A.
59012n	0	N.A.	48.8	50.8	51.4	54.2	N.A.	2.0	0.6	2.8	N.A.	2.6	3.4	N.A.	5.4	N.A.
	0.5	N.A.	41.0	43.2	43.4	46.8	N.A.	2.2	0.2	3.4	N.A.	2.4	3.6	N.A.	5.8	N.A.
	1	N.A.	48.0	50.0	51.0	53.2	N.A.	2.0	1.0	2.2	N.A.	3.0	3.2	N.A.	5.2	N.A.
	1.5	N.A.	49.0	55.2	56.0	56.0	N.A.	6.2	0.8	0.0	N.A.	7.0	0.8	N.A.	7.0	N.A.
	2	N.A.	53.4	58.2	58.0	60.6	N.A.	4.8	-0.2	2.6	N.A.	4.6	2.4	N.A.	7.2	N.A.
	2.5	N.A.	60.4	64.8	64.2	70.2	N.A.	4.4	-0.6	6.0	N.A.	3.8	5.4	N.A.	9.8	N.A.
	3	N.A.	53.6	51.2	53.0	57.2	N.A.	-2.4	1.8	4.2	N.A.	-0.6	6.0	N.A.	3.6	N.A.
	3.5	N.A.	56.0	56.6	59.2	62.4	N.A.	0.6	2.6	3.2	N.A.	3.2	5.8	N.A.	6.4	N.A.
	4	N.A.	53.4	54.2	55.4	59.4	N.A.	0.8	1.2	4.0	N.A.	2.0	5.2	N.A.	6.0	N.A.
	4.5	N.A.	40.6	42.0	42.0	47.0	N.A.	1.4	0.0	5.0	N.A.	1.4	5.0	N.A.	8.4	N.A.
	5	N.A.	39.8	40.2	43.4	45.6	N.A.	0.4	3.2	2.2	N.A.	3.6	5.4	N.A.	5.8	N.A.
	5.5	N.A.	43.8	45.2	46.6	43.0	N.A.	1.5	1.4	-3.6	N.A.	2.9	-2.2	N.A.	-0.8	N.A.
	6	N.A.	39.8	39.4	40.4	44.8	N.A.	-0.4	1.0	4.4	N.A.	0.6	5.4	N.A.	5.0	N.A.
	6.5	N.A.	40.0	41.2	42.6	45.8	N.A.	1.2	1.4	3.2	N.A.	2.6	4.6	N.A.	5.8	N.A.
	7	N.A.	40.0	49.6	49.0	43.5	N.A.	9.6	-0.6	-5.5	N.A.	9.0	-8.1	N.A.	3.5	N.A.
	7.5	N.A.	44.6	44.2	45.6	48.4	N.A.	-0.4	1.4	2.8	N.A.	1.0	4.2	N.A.	3.8	N.A.
	8	N.A.	40.2	39.8	40.8	40.5	N.A.	-0.4	1.0	-0.3	N.A.	0.6	0.7	N.A.	0.3	N.A.
	8.5	N.A.	34.8	35.4	38.6	39.6	N.A.	0.6	3.2	1.0	N.A.	3.8	4.2	N.A.	4.8	N.A.
	9	N.A.	41.8	41.8	42.6	45.8	N.A.	0.0	0.8	3.2	N.A.	0.8	4.0	N.A.	4.0	N.A.

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	96	93-92	94-93	95-94	96-95	94-92	95-93	96-94	95-92	96-93	96-92
59012s	0	N.A.	51.2	50.8	52.4	54.2	N.A.	-0.4	1.6	1.6	N.A.	1.2	3.4	N.A.	3.0	N.A.
	0.5	N.A.	49.8	50.4	50.6	53.6	N.A.	0.6	0.2	3.0	N.A.	0.8	3.2	N.A.	3.8	N.A.
	1	N.A.	43.2	44.8	44.2	47.8	N.A.	1.6	-0.8	3.8	N.A.	1.0	3.0	N.A.	4.6	N.A.
	1.5	N.A.	46.2	45.6	47.6	50.2	N.A.	-0.6	2.0	2.8	N.A.	1.4	4.6	N.A.	4.0	N.A.
	2	N.A.	49.4	48.0	49.8	50.6	N.A.	-1.4	1.6	1.0	N.A.	0.2	2.6	N.A.	1.2	N.A.
	2.5	N.A.	51.0	53.2	52.6	53.6	N.A.	2.2	-0.6	1.0	N.A.	1.6	0.4	N.A.	2.6	N.A.
	3	N.A.	57.6	59.6	58.4	60.2	N.A.	2.0	-1.2	1.8	N.A.	0.8	0.6	N.A.	2.8	N.A.
	3.5	N.A.	54.4	56.6	56.2	60.8	N.A.	2.2	-0.4	4.6	N.A.	1.8	4.2	N.A.	6.4	N.A.
	4	N.A.	47.8	47.6	48.8	52.6	N.A.	-0.2	1.0	4.0	N.A.	0.8	5.0	N.A.	4.8	N.A.
	4.5	N.A.	42.8	42.4	44.0	47.8	N.A.	-0.4	1.8	3.8	N.A.	1.2	5.4	N.A.	5.0	N.A.
	5	N.A.	43.2	43.0	50.0	48.0	N.A.	-0.2	7.0	-2.0	N.A.	6.8	5.0	N.A.	4.8	N.A.
	5.5	N.A.	50.3	51.8	50.8	53.7	N.A.	1.8	-1.0	2.9	N.A.	0.5	1.9	N.A.	3.4	N.A.
	6	N.A.	39.6	39.6	41.2	45.0	N.A.	0.0	1.6	3.8	N.A.	1.8	5.4	N.A.	5.4	N.A.
	6.5	N.A.	45.4	45.0	47.0	48.6	N.A.	-0.4	2.0	1.8	N.A.	1.6	3.6	N.A.	3.2	N.A.
	7	N.A.	47.5	50.0	50.8	52.0	N.A.	2.5	0.8	1.2	N.A.	3.3	2.0	N.A.	4.5	N.A.
	7.5	N.A.	44.6	43.8	48.0	48.0	N.A.	-0.8	4.2	0.0	N.A.	3.4	4.2	N.A.	3.4	N.A.
	8	N.A.	42.6	40.4	41.8	45.8	N.A.	-2.2	1.4	4.0	N.A.	-0.8	5.4	N.A.	3.2	N.A.
	8.5	N.A.	40.6	38.4	40.2	45.8	N.A.	-2.2	1.8	5.6	N.A.	-0.4	7.4	N.A.	5.2	N.A.
	9	N.A.	39.6	37.8	40.0	43.8	N.A.	-1.8	2.2	3.8	N.A.	0.4	6.0	N.A.	4.2	N.A.
25132n	0	48.8	52.4	55.4	53.0	61.4	3.8	3.0	-2.4	8.4	6.6	0.6	6.0	4.2	9.0	12.6
	0.5	55.0	52.2	54.6	53.0	59.2	-2.8	2.4	-1.6	6.2	-0.4	0.8	4.6	-2.0	7.0	4.2
	1	54.6	55.4	60.2	52.4	58.6	0.8	4.8	-7.8	6.2	5.6	-3.0	-1.6	-2.2	3.2	4.0
	1.5	57.4	56.8	57.4	56.6	62.4	-0.6	0.8	-0.8	5.8	0.0	-0.2	5.0	-0.8	5.6	5.0
	2	58.2	55.4	58.2	57.8	63.2	-2.8	2.8	-0.4	5.4	0.0	2.4	5.0	-0.4	7.8	5.0
	2.5	65.0	66.4	65.6	65.0	69.4	1.4	-0.8	-0.6	4.4	0.6	-1.4	3.8	0.0	3.0	4.4
	3	55.0	53.4	57.0	55.4	59.6	-1.6	3.8	-1.6	4.2	2.0	2.0	2.6	0.4	6.2	4.6
	3.5	51.4	56.0	53.6	52.2	57.2	4.6	-2.4	-1.4	5.0	2.2	-3.6	3.6	0.8	1.2	5.8
	4	55.0	53.2	56.8	58.4	59.4	-1.8	3.6	1.8	1.0	1.8	5.2	2.8	3.4	6.2	4.4
	4.5	59.8	60.0	65.0	58.8	63.2	0.2	5.0	-6.2	4.4	5.2	-1.2	-1.8	-1.0	3.2	3.4
	5	62.6	60.8	65.0	67.0	67.4	-1.8	4.2	2.0	0.4	2.4	6.2	2.4	4.4	6.6	4.8
	5.5	52.0	53.0	61.6	53.8	60.0	1.0	8.8	-7.8	6.2	9.6	0.8	-1.6	1.8	7.0	8.0
	6	57.8	56.6	65.2	62.8	65.6	-1.2	8.6	-2.4	2.8	7.4	6.2	0.4	5.0	9.0	7.8
25132s	0	68.3	60.8	64.5	57.7	67.0	-7.5	3.8	-6.8	9.3	-3.8	-3.1	2.5	-10.6	6.3	-1.3
	0.5	59.2	60.2	60.8	59.8	69.2	1.0	0.6	-1.0	9.4	1.6	-0.4	8.4	0.6	9.0	10.0
	1	55.4	53.6	58.4	56.8	62.4	-1.8	4.8	-1.6	5.6	3.0	3.2	4.0	1.4	8.8	7.0
	1.5	56.6	55.0	58.0	53.8	61.6	-1.8	3.0	-4.2	7.8	1.4	-1.2	3.6	-2.8	6.6	5.0
	2	56.6	54.8	57.6	57.4	63.0	-1.8	2.8	-0.2	5.6	1.0	2.8	5.4	0.8	8.2	6.4
	2.5	61.8	55.5	57.8	57.3	64.3	-6.3	2.3	-0.5	7.0	-4.0	1.8	6.5	-4.5	8.8	2.5
	3	57.0	61.2	59.2	57.8	63.6	4.2	-2.0	-1.4	5.8	2.2	-3.4	4.4	0.8	2.4	6.6
	3.5	54.0	55.4	54.4	54.0	59.0	1.4	-1.0	-0.4	5.0	0.4	-1.4	4.6	0.0	3.6	5.0
	4	53.6	52.4	51.6	52.6	56.0	-1.2	-0.8	1.0	3.4	-2.0	0.2	4.4	-1.0	3.6	2.4
	4.5	55.0	57.0	61.7	53.7	59.7	2.0	4.7	-8.0	6.0	6.7	-3.3	-2.0	-1.3	2.7	4.7
	5	66.3	59.7	56.7	57.0	71.3	-6.7	-3.0	0.3	14.3	-9.7	-2.7	14.7	-9.3	11.7	5.0
	5.5	56.0	54.0	61.4	59.3	62.2	-2.0	7.4	-2.2	3.0	5.4	5.3	0.8	3.3	8.2	6.2
	6	54.5	59.0	64.8	60.7	57.3	4.5	5.8	-4.1	-3.3	10.3	1.7	-7.4	6.2	-1.7	2.8

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	96	93-92	94-93	95-94	96-95	94-92	95-93	96-94	95-92	96-93	96-92
13074n	4	61.8	60.8	63.0	60.4	61.2	-1.0	2.2	-2.6	0.8	1.2	-0.4	-1.8	-1.4	0.4	-0.6
	4.5	66.2	86.2	68.0	67.2	87.8	0.0	1.8	-0.8	0.6	1.8	1.0	-0.2	1.0	1.6	1.6
	5	68.4	68.6	69.4	69.4	70.2	0.2	0.8	0.0	0.8	1.0	0.6	0.8	1.0	1.6	1.8
	5.5	65.0	65.6	66.2	66.4	67.0	0.6	0.6	0.2	0.6	1.2	0.8	0.8	1.4	1.4	2.0
	6	57.2	58.2	58.8	58.4	60.0	1.0	0.8	-0.4	1.8	1.8	0.2	1.2	1.2	1.8	2.8
	6.5	56.4	55.2	57.2	57.6	58.6	-1.2	2.0	0.4	1.0	0.8	2.4	1.4	1.2	3.4	2.2
	7	57.8	57.8	58.4	58.8	81.8	-0.2	0.8	0.4	3.0	0.6	1.2	3.4	1.0	4.2	4.0
	7.5	60.8	60.4	61.0	60.2	62.8	-0.4	0.6	-0.8	2.6	0.2	-0.2	1.8	-0.6	2.4	2.0
	8	58.0	58.8	59.6	59.2	62.0	0.8	0.8	-0.4	2.8	1.6	0.4	2.4	1.2	3.2	4.0
	8.5	64.8	64.6	65.2	85.2	67.4	-0.2	0.6	0.0	2.2	0.4	0.6	2.2	0.4	2.8	2.6
13074s	4	65.0	65.6	64.4	68.2	69.8	0.6	-1.2	1.8	3.8	-0.6	0.8	5.4	1.2	4.2	4.8
	4.5	61.0	62.2	61.0	60.8	64.0	1.2	-1.2	-0.2	3.2	0.0	-1.4	3.0	-0.2	1.8	3.0
	5	63.6	64.6	64.2	67.4	70.2	0.8	-0.4	3.2	2.8	0.4	2.8	8.0	3.6	5.8	6.4
	5.5	63.8	63.8	63.8	64.2	69.8	0.0	0.0	0.4	5.6	0.0	0.4	8.0	0.4	6.0	6.0
	6	57.6	59.2	60.0	60.8	64.0	1.6	0.8	0.8	3.2	2.4	1.6	4.0	3.2	4.8	6.4
	6.5	81.6	80.4	61.0	80.8	64.4	-1.2	0.6	-0.4	3.8	-0.6	0.2	3.4	-1.0	4.0	2.8
	7	80.4	58.6	61.4	59.8	66.4	-1.8	2.8	-1.6	6.8	1.0	1.2	5.0	-0.6	7.8	6.0
	7.5	65.2	61.6	62.4	63.0	89.0	-3.8	0.8	0.6	6.0	-2.8	1.4	6.6	-2.2	7.4	3.8
	8	60.8	59.6	59.8	60.4	63.6	-1.2	0.2	0.6	3.4	-1.0	0.8	4.0	-0.4	4.2	3.0
	8.5	67.6	67.0	67.4	66.8	69.6	-0.6	0.4	-0.6	2.8	-0.2	-0.2	2.2	-0.8	2.6	2.0
23061n	0	N.A.	66.2	70.6	71.0	68.2	N.A.	2.4	0.4	-2.8	N.A.	2.8	-2.4	N.A.	0.0	N.A.
	0.5	N.A.	74.4	76.2	76.4	73.2	N.A.	1.8	0.2	-3.2	N.A.	2.0	-3.0	N.A.	-1.2	N.A.
	1	N.A.	69.4	70.2	70.8	69.2	N.A.	0.8	0.6	-1.8	N.A.	1.4	-1.0	N.A.	-0.2	N.A.
	1.5	N.A.	65.0	66.8	67.0	66.6	N.A.	1.8	0.2	-0.2	N.A.	2.0	0.0	N.A.	1.8	N.A.
	2	N.A.	85.0	67.2	88.6	66.8	N.A.	2.2	1.4	-1.8	N.A.	3.6	-0.4	N.A.	1.8	N.A.
	2.5	N.A.	63.2	63.8	65.0	65.8	N.A.	0.8	1.2	0.8	N.A.	1.8	2.0	N.A.	2.6	N.A.
	3	N.A.	63.0	66.0	67.3	63.0	N.A.	3.0	1.3	-4.3	N.A.	4.3	-3.0	N.A.	0.0	N.A.
	3.5	N.A.	63.0	64.0	65.6	63.2	N.A.	1.0	1.6	-2.4	N.A.	2.6	-0.8	N.A.	0.2	N.A.
	4	N.A.	66.4	65.6	66.4	67.6	N.A.	-0.8	0.8	1.2	N.A.	0.0	2.0	N.A.	1.2	N.A.
	4.5	N.A.	66.4	67.0	68.4	69.4	N.A.	0.8	1.4	1.0	N.A.	2.0	2.4	N.A.	3.0	N.A.
	5	N.A.	68.7	70.7	69.0	69.0	N.A.	2.0	-1.7	0.0	N.A.	0.3	-1.7	N.A.	0.3	N.A.
	5.5	N.A.	62.8	65.0	67.2	66.4	N.A.	2.2	2.2	-0.8	N.A.	4.4	1.4	N.A.	3.6	N.A.
	6	N.A.	72.2	73.2	73.2	72.4	N.A.	1.0	0.0	-0.8	N.A.	1.0	-0.8	N.A.	0.2	N.A.
	6.5	N.A.	72.0	72.6	73.6	75.0	N.A.	0.6	1.0	1.4	N.A.	1.6	2.4	N.A.	3.0	N.A.
	7	N.A.	73.8	77.4	76.6	74.8	N.A.	3.6	-0.8	-1.8	N.A.	2.8	-2.6	N.A.	1.0	N.A.
	7.5	N.A.	81.2	85.0	85.4	80.2	N.A.	3.8	0.4	-5.2	N.A.	4.2	-4.8	N.A.	-1.0	N.A.
	8	N.A.	72.0	75.0	73.6	70.8	N.A.	3.0	-1.4	-2.8	N.A.	1.6	-4.2	N.A.	-1.2	N.A.
	8.5	N.A.	65.0	70.6	69.0	70.8	N.A.	5.8	-1.6	1.8	N.A.	4.0	0.2	N.A.	5.8	N.A.
	9	N.A.	67.6	73.2	70.6	70.6	N.A.	5.6	-2.6	0.0	N.A.	3.0	-2.6	N.A.	3.0	N.A.
23061s	0	N.A.	71.2	72.4	75.2	74.2	N.A.	1.2	2.8	-1.0	N.A.	4.0	1.8	N.A.	3.0	N.A.
	0.5	N.A.	60.4	64.8	65.0	65.0	N.A.	4.4	0.2	0.0	N.A.	4.6	0.2	N.A.	4.6	N.A.
	1	N.A.	64.6	67.4	66.4	69.8	N.A.	2.8	-1.0	3.4	N.A.	1.8	2.4	N.A.	5.2	N.A.
	1.5	N.A.	61.0	64.8	64.0	64.0	N.A.	3.8	-0.8	0.0	N.A.	3.0	-0.8	N.A.	3.0	N.A.
	2	N.A.	58.0	57.8	59.2	61.2	N.A.	-0.2	1.4	2.0	N.A.	1.2	3.4	N.A.	3.2	N.A.
	2.5	N.A.	54.8	55.4	56.0	57.2	N.A.	0.6	0.6	1.2	N.A.	1.2	1.8	N.A.	2.4	N.A.
	3	N.A.	65.8	66.8	65.0	63.3	N.A.	1.0	-1.8	-1.7	N.A.	-0.8	-3.4	N.A.	-2.4	N.A.

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	96	93-92	94-93	95-94	96-95	94-92	95-93	96-94	95-92	96-93	96-92
23061s	3.5	N.A.	61.4	64.2	65.2	62.8	N.A.	2.8	1.0	-2.4	N.A.	3.8	-1.4	N.A.	1.4	N.A.
	4	N.A.	64.6	62.6	66.6	64.4	N.A.	-2.0	4.0	-2.2	N.A.	2.0	1.8	N.A.	-0.2	N.A.
	4.5	N.A.	61.2	64.2	63.6	61.4	N.A.	3.0	-0.6	-2.2	N.A.	2.4	-2.8	N.A.	0.2	N.A.
	5	N.A.	61.0	59.7	65.0	67.5	N.A.	-1.3	5.3	2.5	N.A.	4.0	7.8	N.A.	8.5	N.A.
	5.5	N.A.	64.6	67.2	64.5	69.6	N.A.	2.6	-2.7	5.1	N.A.	-0.1	2.4	N.A.	5.0	N.A.
	6	N.A.	65.4	68.4	69.6	70.8	N.A.	3.0	1.2	1.2	N.A.	4.2	2.4	N.A.	5.4	N.A.
	6.5	N.A.	69.4	76.2	76.0	76.2	N.A.	6.8	-0.2	0.2	N.A.	6.6	0.0	N.A.	6.8	N.A.
	7	N.A.	64.0	68.2	67.4	67.6	N.A.	4.2	-0.8	0.2	N.A.	3.4	-0.6	N.A.	3.6	N.A.
	7.5	N.A.	68.4	73.0	71.0	71.8	N.A.	4.8	-2.0	0.8	N.A.	2.6	-1.2	N.A.	3.4	N.A.
	8	N.A.	71.4	75.0	75.2	75.8	N.A.	3.6	0.2	0.6	N.A.	3.8	0.8	N.A.	4.4	N.A.
	8.5	N.A.	63.0	64.2	65.0	65.0	N.A.	1.2	0.8	0.0	N.A.	2.0	0.8	N.A.	2.0	N.A.
	9	N.A.	64.2	65.0	66.5	67.6	N.A.	0.8	3.5	-0.9	N.A.	4.3	2.6	N.A.	3.4	N.A.
44043e	0	75.6	77.2	79.2	79.0	81.4	1.6	2.0	-0.2	2.4	3.6	1.8	2.2	3.4	4.2	5.8
	0.5	70.8	83.4	78.2	76.2	76.8	12.6	-5.2	-2.0	0.8	7.4	-7.2	-1.4	5.4	-6.6	6.0
	1	67.6	70.8	72.6	72.2	75.8	3.2	1.8	-0.4	3.6	5.0	1.4	3.2	4.6	5.0	8.2
	1.5	67.6	74.0	72.8	71.0	75.8	6.4	-1.2	-1.8	4.8	5.2	-3.0	3.0	3.4	1.8	8.2
	2	72.6	76.8	79.4	74.2	80.0	4.2	2.6	-5.2	5.8	6.6	-2.6	0.6	1.6	3.2	7.4
	2.5	69.6	72.4	78.2	71.2	72.8	2.8	5.8	-7.0	1.6	8.6	-1.2	-5.4	1.6	0.4	3.2
	3	67.4	70.6	74.8	71.6	74.4	3.2	4.2	-3.2	2.8	7.4	1.0	-0.4	4.2	3.8	7.0
	3.5	66.0	70.0	71.2	68.6	71.0	4.0	1.2	-2.6	2.4	5.2	-1.4	-0.2	2.6	1.0	5.0
	4	62.2	65.6	65.4	63.4	69.8	3.4	-0.2	-2.0	6.4	3.2	-2.2	4.4	1.2	4.2	7.6
	4.5	65.8	69.6	70.8	70.2	74.0	3.8	1.0	-0.4	3.8	4.8	0.6	3.4	4.4	4.4	8.2
	5	61.0	63.0	63.2	64.6	67.4	2.0	0.2	1.4	2.8	2.2	1.6	4.2	3.6	4.4	6.4
	5.5	63.5	65.8	65.8	68.5	74.3	2.3	0.0	2.8	5.8	2.3	2.8	8.6	5.0	8.6	10.8
	6	66.4	68.4	71.2	65.6	67.8	2.0	2.8	-5.6	2.2	4.8	-2.8	-3.4	-0.8	-0.6	1.4
	6.5	56.4	58.2	57.6	59.2	60.6	1.8	-0.6	1.6	1.4	1.2	1.0	3.0	2.8	2.4	4.2
44043w	0	68.6	69.2	70.4	66.8	73.8	0.6	1.2	-3.7	7.1	1.6	-2.5	3.4	-1.8	4.6	5.2
	0.5	66.4	68.6	76.8	69.4	69.2	2.2	8.2	-7.4	-0.2	10.4	0.8	-7.6	3.0	0.6	2.8
	1	69.2	76.2	75.6	69.6	75.0	7.0	-0.8	-6.0	5.4	6.4	-6.6	-0.6	0.4	-1.2	5.8
	1.5	63.2	67.0	66.2	66.2	68.6	3.8	-0.8	0.0	2.4	3.0	-0.8	2.4	3.0	1.6	5.4
	2	66.8	72.6	72.4	71.6	72.6	5.8	-0.2	-0.8	1.0	5.6	-1.0	0.2	4.8	0.0	5.8
	2.5	65.4	70.4	72.4	66.8	70.6	5.0	2.0	-5.6	3.8	7.0	-3.6	-1.8	1.4	0.2	5.2
	3	61.0	63.8	64.4	66.0	67.6	2.8	0.6	1.6	1.6	3.4	2.2	3.2	5.0	3.8	6.6
	3.5	62.6	66.6	68.4	66.8	70.0	4.0	1.8	-1.8	3.4	5.8	0.0	1.6	4.0	3.4	7.4
	4	65.6	71.4	70.0	72.6	72.2	5.8	-1.4	2.6	-0.4	4.4	1.2	2.2	7.0	0.8	6.6
	4.5	70.0	74.6	73.8	74.4	77.4	4.6	-0.8	0.6	3.0	3.8	-0.2	3.6	4.4	2.8	7.4
	5	65.0	66.0	68.0	70.4	74.4	1.0	2.0	2.4	4.0	3.0	4.4	6.4	5.4	8.4	9.4
	5.5	72.8	73.0	81.5	66.8	74.8	0.3	8.5	-14.8	8.0	8.8	-6.3	-6.8	-6.0	1.8	2.0
	6	64.6	70.6	72.4	68.4	71.8	6.0	1.8	-4.0	3.4	7.8	-2.2	-0.6	3.8	1.2	7.2
	6.5	53.2	52.4	58.0	59.0	58.2	-0.8	5.6	1.0	-0.8	4.8	6.6	0.2	5.8	5.8	5.0
25084e	0	63.5	70.3	69.3	73.4	71.5	6.8	-1.0	4.2	-1.9	5.8	3.2	2.3	9.9	1.3	8.0
	0.5	70.0	75.4	72.5	74.4	77.8	5.4	-2.9	1.9	3.4	2.5	-1.0	5.3	4.4	2.4	7.8
	1	78.5	77.0	73.7	76.0	76.0	-1.5	-3.3	2.3	0.0	-4.8	-1.0	2.3	-2.5	-1.0	-2.5
	1.5	65.7	70.3	69.3	68.3	70.3	4.7	-1.0	-1.0	2.0	3.7	-2.0	1.0	2.7	0.0	4.7
	2	67.0	67.8	68.3	69.3	70.3	0.8	0.5	1.1	1.0	1.3	1.6	2.1	2.3	2.6	3.3

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	96	93-92	94-93	95-94	96-95	94-92	95-93	96-94	95-92	96-93	96-92
25084e	2.5	63.0	68.3	67.8	68.0	73.5	3.3	1.5	0.3	5.5	4.8	1.8	5.8	5.0	7.3	10.5
	3	56.0	62.8	62.2	62.0	70.4	8.8	-0.6	-0.2	8.4	6.2	-0.8	8.2	6.0	7.6	14.4
	3.5	60.3	76.0	70.0	68.8	74.3	15.8	-6.0	-1.3	5.5	9.8	-7.3	4.3	8.5	-1.8	14.0
	4	59.4	65.6	72.2	65.2	68.4	6.2	6.6	-7.0	3.2	12.8	-0.4	-3.8	5.8	2.8	9.0
	4.5	58.0	65.6	70.8	82.8	83.8	7.8	5.2	-6.2	1.2	12.8	-3.0	-7.0	4.6	-1.8	5.8
	5	58.2	63.6	67.8	61.8	66.4	5.4	4.2	-6.0	4.6	9.6	-1.8	-1.4	3.6	2.8	8.2
	5.5	57.0	67.3	66.8	68.0	68.3	10.3	-0.5	-0.8	2.3	9.8	-1.3	1.5	9.0	1.0	11.3
	6	62.0	65.6	74.6	65.8	68.6	3.6	9.0	-8.8	2.8	12.6	0.2	-6.0	3.8	3.0	6.6
	6.5	65.0	66.8	66.8	68.3	71.0	1.8	0.0	-0.5	4.8	1.8	-0.5	4.3	1.3	4.3	6.0
	7	64.8	66.0	65.6	66.8	70.2	1.2	-0.4	1.2	3.4	0.8	0.8	4.8	2.0	4.2	5.4
	7.5	70.8	71.2	70.6	71.6	75.8	0.4	-0.6	1.0	4.2	-0.2	0.4	5.2	0.8	4.6	5.0
	8	67.8	69.4	71.8	69.8	72.8	1.6	2.4	-2.0	3.0	4.0	0.4	1.0	2.0	3.4	5.0
	8.5	69.0	72.5	72.3	69.0	71.7	3.5	-0.3	-3.3	2.7	3.3	-3.5	-0.8	0.0	-0.8	2.7
	9	70.2	69.8	76.2	70.6	73.0	-0.4	6.4	-5.8	2.4	6.0	0.8	-3.2	0.4	3.2	2.8
	9.5	70.6	70.0	73.0	73.0	76.6	-0.6	3.0	0.0	3.6	2.4	3.0	3.6	2.4	6.8	6.0
	10	63.6	65.4	67.0	68.2	70.6	1.8	1.6	-0.8	4.4	3.4	0.8	3.6	2.6	5.2	7.0
	10.5	63.0	64.6	65.8	66.0	70.0	1.6	1.2	0.2	4.0	2.8	1.4	4.2	3.0	5.4	7.0
	11	61.0	64.2	66.2	63.6	66.4	3.2	2.0	-2.6	2.8	5.2	-0.6	0.2	2.6	2.2	5.4
25084w	0	61.0	63.8	63.3	66.8	68.2	2.8	-0.5	3.5	1.5	2.3	3.0	5.0	5.8	4.5	7.2
	0.5	76.0	74.4	83.0	81.8	85.0	-1.6	8.6	-1.2	3.2	7.0	7.4	2.0	5.8	10.6	9.0
	1	75.5	70.3	74.5	70.7	73.0	-5.3	4.3	-3.8	2.3	-1.0	0.4	-1.5	-4.8	2.8	-2.5
	1.5	68.0	71.0	70.3	71.0	74.0	3.0	-0.7	0.7	3.0	2.3	0.0	3.7	3.0	3.0	6.0
	2	65.8	74.0	71.0	72.3	70.7	8.3	-3.0	1.3	-1.7	5.3	-1.7	-0.3	6.6	-3.3	4.9
	2.5	69.8	79.3	74.3	72.3	74.8	9.5	-5.0	-2.0	2.5	4.5	-7.0	0.5	2.5	-4.5	5.0
	3	61.4	67.6	67.2	68.6	69.2	6.2	-0.4	1.4	0.6	5.8	1.0	2.0	7.2	1.6	7.8
	3.5	56.5	61.5	63.3	65.0	70.3	5.0	1.8	1.8	5.3	6.8	3.5	7.1	8.5	8.8	13.8
	4	59.8	68.6	63.4	N.A.	71.6	8.8	-5.2	N.A.	N.A.	3.6	N.A.	8.2	N.A.	3.0	11.8
	4.5	63.2	67.0	66.8	N.A.	70.8	3.8	-0.2	N.A.	N.A.	3.6	N.A.	3.8	N.A.	3.6	7.4
	5	57.8	63.2	68.4	N.A.	64.8	5.4	5.2	N.A.	N.A.	10.6	N.A.	-3.6	N.A.	1.6	7.0
	5.5	65.5	73.5	73.5	N.A.	75.0	8.0	0.0	N.A.	N.A.	8.0	N.A.	1.5	N.A.	1.5	9.5
	6	67.8	71.8	70.0	N.A.	70.0	4.0	-1.8	N.A.	N.A.	2.2	N.A.	0.0	N.A.	-1.8	2.2
	6.5	67.3	72.0	73.3	N.A.	75.3	4.8	1.3	N.A.	N.A.	6.0	N.A.	2.0	N.A.	3.3	8.0
	7	66.0	65.6	68.6	N.A.	72.2	-0.4	3.0	N.A.	N.A.	2.6	N.A.	3.6	N.A.	6.6	6.2
	7.5	64.4	66.2	67.8	N.A.	69.6	1.8	1.4	N.A.	N.A.	3.2	N.A.	2.0	N.A.	3.4	5.2
	8	58.8	61.8	62.2	N.A.	64.8	2.8	0.6	N.A.	N.A.	3.4	N.A.	2.6	N.A.	3.2	6.0
	8.5	64.3	66.0	69.8	N.A.	73.7	1.8	3.8	N.A.	N.A.	5.5	N.A.	3.9	N.A.	7.7	9.4
	9	61.4	65.0	69.2	N.A.	68.4	3.6	4.2	N.A.	N.A.	7.8	N.A.	-0.8	N.A.	3.4	7.0
	9.5	68.8	67.0	69.2	N.A.	72.8	-1.8	2.2	N.A.	N.A.	0.4	N.A.	3.6	N.A.	5.8	4.0
	10	65.8	66.0	67.8	N.A.	71.4	0.2	1.8	N.A.	N.A.	2.0	N.A.	3.6	N.A.	5.4	5.6
	10.5	66.2	65.8	71.8	N.A.	72.0	-0.4	6.0	N.A.	N.A.	5.6	N.A.	0.2	N.A.	6.2	5.8
	11	65.4	66.6	68.8	N.A.	71.6	1.2	2.2	N.A.	N.A.	3.4	N.A.	2.8	N.A.	5.0	6.2
73101n	5	54.0	56.8	56.0	57.2	58.2	2.8	-0.8	1.2	1.0	2.0	0.4	2.2	3.2	1.4	4.2
	5.5	48.2	45.8	46.2	46.6	48.4	-2.4	0.4	0.4	1.8	-2.0	0.8	2.2	-1.6	2.6	0.2
	6	47.6	49.2	48.8	49.0	52.8	1.8	-0.4	0.2	3.8	1.2	-0.2	4.0	1.4	3.6	5.2
	6.5	46.8	46.6	44.2	44.4	49.6	-0.2	-2.4	0.2	5.2	-2.6	-2.2	5.4	-2.4	3.0	2.8

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	96	93-92	94-93	95-94	96-95	94-92	95-93	96-94	95-92	96-93	96-92
21025e	0	69.0	68.0	67.0	67.6	66.8	-1.0	-1.0	0.6	-0.8	-2.0	-0.4	-0.2	-1.4	-1.2	-2.2
	0.5	60.8	63.4	65.8	64.8	62.0	2.7	2.4	-1.0	-2.8	5.1	1.4	-3.8	4.1	-1.4	1.3
	1	51.2	52.8	52.2	53.4	54.6	1.4	-0.4	1.2	1.2	1.0	0.8	2.4	2.2	2.0	3.4
	1.5	53.2	54.8	54.6	56.0	55.4	1.6	-0.2	1.4	-0.8	1.4	1.2	0.8	2.8	0.6	2.2
	2	48.2	50.4	50.8	50.6	53.2	2.2	0.4	-0.2	2.6	2.8	0.2	2.4	2.4	2.8	5.0
	2.5	52.2	54.0	54.0	54.4	57.4	1.8	0.0	0.4	3.0	1.8	0.4	3.4	2.2	3.4	5.2
	3	59.3	62.2	63.8	66.2	61.0	3.0	1.8	2.4	-5.2	4.8	4.0	-2.8	7.0	-1.2	1.8
	3.5	57.0	58.2	57.8	57.6	55.8	1.2	-0.4	-0.2	-1.6	0.8	-0.6	-2.0	0.6	-2.4	-1.2
	4	52.4	57.6	56.0	55.0	55.8	5.2	-1.8	-1.0	0.8	3.6	-2.8	-0.2	2.6	-1.8	3.4
	4.5	55.2	56.6	59.2	58.8	58.6	1.4	2.8	-0.4	-0.2	4.0	2.2	-0.6	3.6	2.0	3.4
	5	61.2	61.4	62.6	60.8	63.2	0.2	1.2	-1.8	2.4	1.4	-0.6	0.6	-0.4	1.8	2.0
	5.5	58.0	58.6	60.4	59.8	60.0	0.8	1.8	-0.6	0.2	2.4	1.2	-0.4	1.8	1.4	2.0
21025w	0	71.0	72.6	72.8	77.2	71.7	1.6	0.2	4.4	-5.5	1.8	4.6	-1.1	6.2	-0.9	0.7
	0.5	64.0	61.6	61.6	61.6	64.4	-2.4	0.0	0.0	2.8	-2.4	0.0	2.8	-2.4	2.8	0.4
	1	61.2	58.2	59.8	60.8	61.0	-3.0	1.6	1.0	0.2	-1.4	2.6	1.2	-0.4	2.8	-0.2
	1.5	53.0	54.6	55.0	55.6	57.0	1.6	0.4	0.6	1.4	2.0	1.0	2.0	2.6	2.4	4.0
	2	49.8	50.8	50.6	51.4	52.0	1.0	-0.2	0.8	0.6	0.8	0.6	1.4	1.6	1.2	2.2
	2.5	50.6	54.8	54.8	55.2	53.8	4.2	0.0	0.4	-1.4	4.2	0.4	-1.0	4.6	-1.0	3.2
	3	53.5	54.8	58.8	59.8	54.5	1.3	4.0	1.0	-5.3	5.3	5.0	-4.3	6.3	-0.3	1.0
	3.5	53.4	53.2	52.6	56.6	57.0	-0.2	-0.6	4.0	0.4	-0.8	3.4	4.4	3.2	3.8	3.6
	4	51.8	52.0	52.0	52.8	52.0	0.2	0.0	0.8	-0.8	0.2	0.8	0.0	1.0	0.0	0.2
	4.5	52.6	52.2	51.2	53.8	53.4	-0.4	-1.0	2.6	-0.4	-1.4	1.6	2.2	1.2	1.2	0.8
	5	57.6	62.2	61.8	62.2	58.6	4.6	-0.4	0.4	-3.6	4.2	0.0	-3.2	4.6	-3.6	1.0
	5.5	68.4	63.0	67.2	66.6	70.0	-5.4	4.2	-0.8	3.4	-1.2	3.6	2.8	-1.8	7.0	1.6
65041n	0	50.6	50.4	51.8	53.8	55.0	-0.2	1.4	2.0	1.2	1.2	3.4	3.2	3.2	4.6	4.4
	0.5	51.2	51.2	50.4	52.4	57.6	0.0	-0.8	2.0	5.2	-0.8	1.2	7.2	1.2	6.4	6.4
	1	49.2	48.2	49.0	50.8	54.2	-1.0	0.8	1.8	3.4	-0.2	2.6	5.2	1.6	6.0	5.0
	1.5	49.2	46.8	47.2	49.4	53.2	-2.4	0.4	2.2	3.8	-2.0	2.6	6.0	0.2	6.4	4.0
	2	51.2	51.8	51.6	53.2	56.8	0.6	-0.2	1.6	3.6	0.4	1.4	5.2	2.0	5.0	5.6
	2.5	44.4	43.6	43.4	48.0	48.8	-0.8	-0.2	2.6	2.8	-1.0	2.4	5.4	1.6	5.2	4.4
	3	58.2	57.0	57.8	58.4	60.4	-1.2	0.8	0.6	2.0	-0.4	1.4	2.6	0.2	3.4	2.2
	3.5	55.6	57.0	56.2	56.4	60.4	1.4	-0.8	0.2	4.0	0.6	-0.6	4.2	0.8	3.4	4.8
	4	57.6	58.4	58.2	59.0	63.8	0.8	-0.2	0.8	4.8	0.6	0.6	5.8	1.4	5.4	6.2
	4.5	54.6	54.8	55.4	56.6	58.8	0.2	0.6	1.2	2.2	0.8	1.8	3.4	2.0	4.0	4.2
	5	59.4	59.4	60.4	61.4	64.8	0.0	1.0	1.0	3.4	1.0	2.0	4.4	2.0	5.4	5.4
	5.5	55.2	55.0	55.8	56.8	59.4	-0.2	0.8	0.8	2.8	0.6	1.6	3.6	1.4	4.4	4.2
	6	59.0	60.6	61.4	62.2	65.6	1.8	0.8	0.8	3.4	2.4	1.8	4.2	3.2	5.0	6.6
65041s	0	57.0	58.6	58.8	58.4	62.0	1.6	0.2	-0.4	3.8	1.8	-0.2	3.2	1.4	3.4	5.0
	0.5	56.0	56.6	58.6	58.0	62.8	0.6	2.0	-0.6	4.8	2.6	1.4	4.2	2.0	6.2	6.8
	1	53.2	54.8	53.4	56.6	60.4	1.6	-1.4	3.2	3.8	0.2	1.8	7.0	3.4	5.6	7.2
	1.5	53.0	55.4	55.4	57.0	60.6	2.4	0.0	1.6	3.6	2.4	1.6	5.2	4.0	5.2	7.6
	2	53.6	55.0	55.4	57.0	61.6	1.4	0.4	1.6	4.6	1.8	2.0	6.2	3.4	6.6	8.0
	2.5	50.4	52.8	51.4	54.0	58.2	2.4	-1.4	2.6	4.2	1.0	1.2	6.8	3.6	5.4	7.8
	3	48.8	49.0	48.2	50.0	55.6	0.2	-0.8	1.8	5.6	-0.6	1.0	7.4	1.2	6.6	6.8
	3.5	49.2	49.0	48.8	50.4	57.6	-0.2	-0.2	1.6	7.2	-0.4	1.4	8.8	1.2	8.6	8.4

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	96	93-92	94-93	95-94	96-95	94-92	95-93	96-94	95-92	96-93	96-92
65041s	4	46.0	46.8	46.2	48.0	53.2	0.8	-0.6	1.8	5.2	0.2	1.2	7.0	2.0	6.4	7.2
	4.5	48.2	48.6	49.4	50.2	56.6	0.4	0.6	0.6	6.4	1.2	1.6	7.2	2.0	8.0	8.4
	5	56.8	56.4	57.2	59.2	65.4	1.6	-1.2	2.0	6.2	0.4	0.8	8.2	2.4	7.0	8.6
	5.5	49.4	53.2	49.6	52.2	58.4	3.8	-3.6	2.6	6.2	0.2	-1.0	8.8	2.8	5.2	9.0
	6	57.2	56.6	60.2	60.0	64.8	1.4	1.8	-0.2	4.8	3.0	1.4	4.6	2.8	6.2	7.6
25085e	1	55.6	59.6	N.A.	61.0	64.2	4.0	N.A.	N.A.	3.2	N.A.	1.4	N.A.	5.4	4.6	6.6
	1.5	53.8	56.3	N.A.	63.0	61.7	4.5	N.A.	N.A.	-1.3	N.A.	4.8	N.A.	9.3	3.4	7.9
	2	58.0	61.5	N.A.	59.7	63.0	3.5	N.A.	N.A.	3.3	N.A.	-1.8	N.A.	1.7	1.5	5.0
	2.5	54.8	57.4	N.A.	55.2	57.6	2.6	N.A.	N.A.	2.4	N.A.	-2.2	N.A.	0.4	0.2	2.8
25085w	1	61.4	67.2	61.8	66.6	68.6	5.8	-5.4	4.8	2.0	0.4	-0.6	6.8	5.2	1.4	7.2
	1.5	63.8	65.4	65.2	67.6	68.5	1.7	-0.2	2.4	0.9	1.5	2.2	3.3	3.8	3.1	4.8
	2	65.3	68.0	72.4	65.6	66.0	2.8	4.4	-6.8	0.4	7.2	-2.4	-6.4	0.3	-2.0	0.8
	2.5	58.8	63.8	63.6	68.0	65.6	5.0	0.0	4.4	-2.4	5.0	4.4	2.0	9.4	2.0	7.0
06111n	0	56.8	60.4	62.2	67.4	60.2	3.6	1.8	5.2	-7.2	5.4	7.0	-2.0	10.8	-0.2	3.4
	0.5	47.6	54.7	53.2	59.4	54.4	7.1	-1.5	6.2	-5.0	5.8	4.7	1.2	11.8	-0.3	6.8
	1	62.0	67.4	67.8	70.6	64.0	5.4	0.4	2.8	-6.6	5.8	3.2	-3.8	8.6	-3.4	2.0
	1.5	60.6	61.2	64.8	67.8	64.8	0.6	3.4	3.2	-3.0	4.0	6.6	0.2	7.2	3.6	4.2
	2	60.6	61.8	58.6	68.0	62.8	1.2	-3.2	9.4	-5.2	-2.0	6.2	4.2	7.4	1.0	2.2
	2.5	39.2	36.2	36.6	39.0	43.2	-3.0	0.4	2.4	4.2	-2.6	2.8	6.6	-0.2	7.0	4.0
	3	42.6	41.8	42.0	44.2	46.4	-0.8	0.2	2.2	4.2	-0.6	2.4	6.4	1.6	6.6	5.8
	3.5	50.0	47.2	49.0	50.2	57.0	-2.8	1.8	1.2	6.8	-1.0	3.0	6.0	0.2	9.8	7.0
	4	52.2	51.2	55.4	54.6	59.2	-1.0	4.2	-0.6	4.4	3.2	3.6	3.8	2.8	8.0	7.0
	4.5	49.3	49.5	56.3	54.5	61.0	0.3	6.8	-1.8	6.5	7.0	5.0	4.8	5.3	11.5	11.8
	5	55.8	61.6	67.0	64.5	66.8	5.8	5.4	-2.5	2.3	11.2	2.9	-0.3	8.7	5.2	11.0
	5.5	49.2	46.8	50.6	51.0	57.6	-2.4	3.8	0.4	6.6	1.4	4.2	7.0	1.8	10.8	8.4
	6	45.8	45.0	44.6	45.6	50.8	-0.8	-0.4	1.0	5.2	-1.2	0.6	6.2	-0.2	5.8	5.0
	6.5	48.2	48.2	46.8	51.2	53.0	0.0	0.8	2.4	1.8	0.8	3.0	4.2	3.0	4.8	4.8
	7	46.4	46.0	48.6	51.4	51.8	-0.4	2.6	2.8	0.4	2.2	5.4	3.2	5.0	5.8	5.4
	7.5	56.4	58.6	59.3	65.6	67.2	2.2	0.7	6.3	1.6	2.9	7.0	7.9	9.2	8.6	10.8
	8	52.0	53.4	52.6	55.8	57.8	1.4	-0.8	3.0	2.0	0.6	2.4	5.0	3.8	4.4	5.8
	8.5	59.0	64.2	60.4	68.0	70.0	5.2	-3.8	7.6	2.0	1.4	3.6	9.6	9.0	5.8	11.0
	9	54.4	54.6	57.6	61.6	58.8	0.2	3.0	4.0	-2.8	3.2	7.0	1.2	7.2	4.2	4.4
	9.5	51.2	59.2	51.8	53.6	55.2	8.0	-7.4	1.8	1.6	0.6	-5.6	3.4	2.4	-4.0	4.0
	10	43.2	42.4	44.0	51.4	52.4	-0.8	1.6	7.4	1.0	0.8	9.0	8.4	8.2	10.0	9.2
	10.5	42.0	43.0	42.4	47.0	47.6	1.0	-0.6	4.6	0.6	0.4	4.0	5.2	5.0	4.6	5.6
	11	48.4	49.0	50.2	49.0	55.2	0.6	1.2	-1.2	6.2	1.8	0.0	5.0	0.8	6.2	6.8
	11.5	51.6	51.2	52.8	57.8	58.0	-0.4	1.6	5.0	0.2	1.2	6.6	5.2	6.2	6.8	8.4
	12	59.6	57.0	61.2	63.4	68.6	-2.8	4.2	2.2	5.4	1.4	6.4	7.6	3.6	11.8	9.0
	12.5	61.6	59.4	63.6	64.4	67.2	-2.2	4.2	0.8	2.8	2.0	5.0	3.6	2.8	7.8	5.6
	13	49.4	46.4	49.4	50.8	56.0	-3.0	3.0	1.4	5.2	0.0	4.4	6.6	1.4	9.6	6.6
	13.5	55.4	57.4	53.4	56.4	60.8	2.0	-4.0	3.0	4.4	-2.0	-1.0	7.4	1.0	3.4	5.4
	14	51.6	47.6	49.2	53.6	55.8	-4.0	1.6	4.4	2.2	-2.4	6.0	6.6	2.0	8.2	4.2
	14.5	47.0	44.6	53.8	53.4	57.4	-2.4	9.2	-0.4	4.0	6.8	8.8	3.6	6.4	12.8	10.4
	15	52.0	56.0	55.4	58.6	62.6	4.0	-0.6	3.2	4.0	3.4	2.6	7.2	6.6	6.6	10.6
	15.5	48.4	53.6	51.8	57.6	56.6	5.4	-2.0	5.8	-1.0	3.4	3.8	4.8	9.2	2.6	8.2

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	96	93-92	94-93	95-94	96-95	94-92	95-93	96-94	95-92	96-93	96-92
	16	53.2	56.8	52.2	53.4	65.2	3.6	-4.6	1.2	11.8	-1.0	-3.4	13.0	0.2	8.4	12.0
	16.5	46.2	47.4	49.4	57.0	60.4	1.2	2.0	7.6	3.4	3.2	9.6	11.0	10.8	13.0	14.2
	17	57.8	N.A.	63.2	N.A.	67.8	N.A.	N.A.	N.A.	N.A.	5.4	N.A.	4.6	N.A.	N.A.	10.0
06111s	0	61.0	60.6	56.8	64.2	63.8	-0.4	-4.0	7.6	-0.4	-4.4	3.6	7.2	3.2	3.2	2.6
	0.5	46.4	56.6	55.4	57.4	62.6	10.2	-1.2	2.0	5.4	9.0	0.8	7.4	11.0	6.2	16.4
	1	55.0	57.6	58.4	82.8	[illegible]	2.6	0.8	4.4	-1.8	3.4	5.2	2.8	7.8	3.8	6.2
	1.5	47.4	55.4	57.4	57.4	61.6	8.0	2.0	0.0	4.2	10.0	2.0	4.2	10.0	6.2	14.2
	2	50.6	48.4	48.6	50.2	51.2	-2.2	0.2	1.8	1.0	-2.0	1.6	2.6	-0.4	2.6	0.6
	2.5	37.2	39.4	41.8	44.6	46.8	2.2	2.4	2.8	2.2	4.6	5.2	5.0	7.4	7.4	9.6
	3	51.2	51.0	48.0	54.2	57.2	-0.2	-3.0	6.2	3.0	-3.2	3.2	9.2	3.0	6.2	6.0
	3.5	47.8	46.2	47.0	49.2	51.8	-1.4	0.8	2.2	2.6	-0.6	3.0	4.8	1.6	5.6	4.2
	4	42.8	43.2	43.8	49.2	45.0	0.4	0.6	5.4	-4.2	1.0	6.0	1.2	6.4	1.8	2.2
	4.5	44.5	46.5	45.8	46.8	51.5	2.0	-0.8	1.0	4.8	1.3	0.3	5.8	2.3	5.0	7.0
	5	55.0	82.2	59.0	55.0	61.3	7.2	-3.2	-4.0	6.3	4.0	-7.2	2.3	0.0	-1.0	6.3
	5.5	52.2	64.6	58.0	64.2	65.6	12.4	-6.6	6.2	1.4	5.8	-0.4	7.6	12.0	1.0	13.4
	6	48.0	61.4	59.0	59.0	63.0	13.4	-2.4	0.0	4.0	11.0	-2.4	4.0	11.0	1.6	15.0
	6.5	63.8	66.2	63.0	61.8	68.6	2.4	-3.2	-1.2	8.8	-0.8	-4.4	5.6	-2.0	2.4	4.8
	7	60.8	63.6	60.8	64.8	66.6	3.0	-3.2	4.2	3.6	-0.2	1.0	8.0	4.0	4.8	7.8
	7.5	52.4	56.8	57.6	58.2	65.8	4.4	0.8	0.8	7.8	5.2	1.4	8.2	5.8	9.0	13.4
	8	49.0	50.0	50.2	58.8	58.6	1.0	0.2	8.8	-0.2	1.2	8.8	8.4	9.6	8.6	9.6
	8.5	54.6	57.2	53.6	55.4	60.0	2.6	-3.8	1.8	4.6	-1.0	-1.8	6.4	0.6	2.8	5.4
	9	48.4	52.4	53.2	54.6	57.6	4.0	0.8	1.4	3.0	4.8	2.2	4.4	6.2	5.2	9.2
	9.5	45.0	42.4	40.2	49.8	45.0	-2.6	-2.2	9.6	-4.8	-4.8	7.4	4.8	4.8	2.6	0.0
	10	42.4	46.6	49.8	54.4	59.6	4.2	3.2	4.8	5.2	7.4	7.8	9.8	12.0	13.0	17.2
	10.5	47.4	50.2	48.0	48.6	50.4	2.8	-2.2	0.6	1.8	0.6	-1.6	2.4	1.2	0.2	3.0
	11	47.2	47.4	52.2	50.2	59.6	0.2	4.8	-2.0	9.6	5.0	2.8	7.6	3.0	12.4	12.6
	11.5	55.2	55.0	57.6	59.4	65.4	-0.2	2.6	1.8	6.0	2.4	4.4	7.8	4.2	10.4	10.2
	12	47.0	49.0	51.6	49.6	54.8	2.0	2.6	-2.0	5.2	4.6	0.6	3.2	2.6	5.8	7.8
	12.5	43.6	46.6	43.6	50.2	54.6	3.0	-3.0	6.8	4.4	0.0	3.6	11.0	6.6	8.0	11.0
	13	42.0	44.0	42.2	48.0	55.2	2.0	-1.8	5.8	7.2	0.2	4.0	13.0	6.0	11.2	13.2
	13.5	39.2	45.8	45.4	44.4	48.0	6.6	-0.4	-1.0	3.8	6.2	-1.4	2.6	5.2	2.2	8.8
	14	44.8	44.0	46.6	46.6	48.8	-0.8	2.6	0.0	2.2	1.8	2.6	2.2	1.8	4.8	4.0
	14.5	52.6	47.0	49.4	53.6	54.0	-5.6	2.4	4.2	0.4	-3.2	6.6	4.6	1.0	7.0	1.4
	15	43.0	46.4	49.6	50.8	54.4	3.4	3.2	1.2	3.6	6.6	4.4	4.8	7.8	8.0	11.4
	15.5	47.0	54.0	51.4	51.2	55.0	7.0	-2.6	-0.2	3.8	4.4	-2.8	3.6	4.2	1.0	8.0
	16	44.4	50.2	48.2	54.2	58.0	5.8	-2.0	6.0	3.8	3.8	4.0	9.8	9.8	7.8	13.6
	16.5	51.8	57.0	49.0	55.4	62.6	5.2	-8.0	6.4	7.2	-2.8	-1.6	13.6	3.6	5.6	10.8
	17	60.2	67.0	63.4	64.4	68.2	6.6	-3.6	1.0	1.8	3.2	-2.6	2.8	4.2	-0.8	6.0
13073n	0.5	57.0	58.0	60.6	61.4	66.0	1.0	2.6	0.8	4.6	3.6	3.4	5.4	4.4	8.0	9.0
	1	58.8	59.8	64.8	63.3	65.5	1.0	5.0	-1.4	2.2	6.0	3.6	0.6	4.6	5.8	6.8
	1.5	53.8	54.8	58.8	59.2	61.2	1.0	4.0	0.4	2.0	5.0	4.4	2.4	5.4	6.4	7.4
	2	56.8	61.8	55.3	57.8	80.3	5.0	-6.5	2.5	2.6	-1.5	-4.0	5.1	1.0	-1.4	3.6
	2.5	50.3	53.5	57.3	59.8	59.5	3.3	3.8	2.5	-0.3	7.0	6.3	2.3	9.5	6.0	9.3
	3	57.0	56.6	56.0	59.6	62.2	-0.4	-0.6	3.8	2.6	-1.0	3.0	8.2	2.6	5.6	5.2
	3.5	58.4	58.2	60.8	80.2	59.8	-0.2	2.6	-0.6	-0.4	2.4	2.0	-1.0	1.8	1.6	1.4

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	98	93-92	94-93	95-94	96-95	94-92	95-93	98-94	95-92	96-93	96-92
13073n	4	58.4	58.8	63.0	59.2	61.4	2.4	4.2	-3.8	2.2	6.6	0.4	-1.6	2.8	2.6	5.0
	4.5	56.2	56.6	62.4	55.6	58.2	0.4	5.8	-8.8	2.6	6.2	-1.0	-4.2	-0.8	1.6	2.0
	5	57.8	59.2	59.8	59.8	62.0	1.4	0.4	0.0	2.4	1.8	0.4	2.4	1.8	2.8	4.2
	5.5	54.8	56.4	55.6	55.0	55.6	1.6	-0.8	-0.6	0.6	0.8	-1.4	0.0	0.2	-0.8	0.8
	6	57.8	58.8	58.2	60.8	81.8	1.0	-0.6	2.6	1.0	0.4	2.0	3.6	3.0	3.0	4.0
	6.5	63.4	64.8	65.4	65.0	68.6	1.4	0.6	-0.4	3.6	2.0	0.2	3.2	1.6	3.8	5.2
	7	54.2	56.6	56.4	57.2	80.8	2.4	-0.2	0.8	3.4	2.2	0.6	4.2	3.0	4.0	6.4
	7.5	59.0	58.4	85.6	82.2	85.8	-0.6	7.2	-3.4	3.6	6.6	3.8	0.2	3.2	7.4	6.8
	8	58.2	57.2	59.2	58.4	60.2	1.0	2.0	-0.8	1.6	3.0	1.2	1.0	2.2	3.0	4.0
	8.5	57.0	58.0	81.2	57.8	60.4	1.0	3.2	-3.4	2.6	4.2	-0.2	-0.8	0.8	2.4	3.4
	9	55.8	56.8	57.8	60.0	60.4	1.2	1.0	2.2	0.4	2.2	3.2	2.6	4.4	3.6	4.8
	9.5	56.2	55.6	58.2	62.0	65.6	-0.6	2.8	3.8	3.8	2.0	6.4	7.4	5.8	10.0	9.4
	10	57.4	57.2	58.0	64.8	66.8	-0.2	0.8	6.8	2.0	0.6	7.6	8.8	7.4	9.6	9.4
	10.5	64.0	63.4	61.4	66.4	67.8	-0.6	-2.0	5.0	1.4	-2.6	3.0	8.4	2.4	4.4	3.8
	11	61.0	63.0	61.8	61.8	62.8	2.0	-1.2	-0.2	1.0	0.8	-1.4	0.8	0.6	-0.4	1.6
	11.5	58.2	58.0	56.4	59.2	60.6	-0.2	-1.6	2.8	1.4	-1.8	1.2	4.2	1.0	2.6	2.4
	12	58.0	56.8	57.0	57.2	61.8	-1.2	0.2	0.2	4.6	-1.0	0.4	4.8	-0.8	5.0	3.8
	12.5	54.4	51.2	52.4	55.8	55.8	-3.2	1.2	3.2	0.2	-2.0	4.4	3.4	1.2	4.6	1.4
	13	58.4	54.2	58.0	57.4	58.0	-2.2	1.8	1.4	0.6	-0.4	3.2	2.0	1.0	3.8	1.6
	13.5	55.8	61.3	57.3	61.0	61.5	5.5	-4.0	3.8	0.5	1.5	-0.3	4.3	5.3	0.3	5.8
	14	47.0	48.8	47.4	48.4	50.4	1.8	-1.2	1.0	2.0	0.4	-0.2	3.0	1.4	1.8	3.4
	14.5	57.0	59.6	58.8	56.6	58.6	2.6	-0.8	-2.2	2.0	1.8	-3.0	-0.2	-0.4	-1.0	1.6
	15	53.2	59.4	57.2	55.0	56.0	8.2	-2.2	-2.2	1.0	4.0	-4.4	-1.2	1.8	-3.4	2.8
	15.5	56.0	56.8	56.2	58.6	56.4	0.8	-0.6	0.4	-0.2	0.2	-0.2	0.2	0.8	-0.4	0.4
13073s	0.5	62.6	58.6	63.4	57.8	60.6	-4.0	4.8	-5.6	2.8	0.8	-0.8	-2.8	-4.8	2.0	-2.0
	1	50.3	51.3	60.0	53.8	56.5	1.0	8.8	-8.3	2.8	9.6	2.5	-3.5	3.5	5.3	6.3
	1.5	47.0	47.8	51.0	50.4	56.8	0.8	3.2	-0.6	6.4	4.0	2.6	5.8	3.4	9.0	9.8
	2	60.0	60.8	66.8	54.3	81.0	0.8	6.0	-12.4	6.7	6.8	-6.4	-5.8	-5.7	0.3	1.0
	2.5	58.8	60.3	65.0	60.0	57.3	1.5	4.8	-5.0	-2.7	6.3	-0.3	-7.7	1.3	-2.9	-1.4
	3	55.6	57.0	59.2	57.8	62.0	1.4	2.2	-1.4	4.2	3.8	0.8	2.8	2.2	5.0	6.4
	3.5	53.6	54.8	57.8	55.8	59.2	1.2	3.0	-2.0	3.4	4.2	1.0	1.4	2.2	4.4	5.6
	4	57.0	55.6	57.6	57.0	60.2	-1.4	2.0	-0.6	3.2	0.6	1.4	2.6	0.0	4.6	3.2
	4.5	50.2	50.2	53.8	53.0	54.8	0.0	3.6	-0.8	1.8	3.6	2.8	1.0	2.8	4.6	4.6
	5	52.2	53.6	61.8	55.4	60.0	1.4	8.2	-6.4	4.6	9.6	1.8	-1.8	3.2	6.4	7.8
	5.5	57.4	60.0	65.2	58.4	60.2	2.6	5.2	-6.8	1.8	7.8	-1.8	-5.0	1.0	0.2	2.8
	6	50.8	51.8	54.0	52.6	52.2	1.0	2.2	-1.4	-0.4	3.2	0.8	-1.8	1.8	0.4	1.4
	6.5	53.4	53.0	55.8	53.0	58.0	-0.4	2.6	-2.6	3.0	2.2	0.0	0.4	-0.4	3.0	2.6
	7	55.0	54.4	56.0	58.2	57.8	-0.6	1.6	0.2	1.6	1.0	1.8	1.8	1.2	3.4	2.8
	7.5	62.8	56.2	58.0	58.0	59.6	-6.6	1.8	0.0	1.6	-4.8	1.8	1.6	-4.8	3.4	-3.2
	8	65.4	61.0	60.4	60.4	66.4	-4.4	-0.6	0.0	6.0	-5.0	-0.6	6.0	-5.0	5.4	1.0
	8.5	61.4	57.4	60.8	80.4	62.0	-4.0	3.4	-0.4	1.6	-0.6	3.0	1.2	-1.0	4.6	0.6
	9	58.0	57.6	59.0	62.2	64.0	-0.4	1.4	3.2	1.8	1.0	4.6	5.0	4.2	6.4	6.0
	9.5	58.6	57.2	60.0	64.4	64.4	-1.4	2.8	4.4	0.0	1.4	7.2	4.4	5.8	7.2	5.8
	10	58.0	54.8	56.6	58.0	60.8	-3.2	1.8	1.4	2.8	-1.4	3.2	4.2	0.0	6.0	2.8
	10.5	63.0	61.0	59.8	62.8	84.8	-2.0	-1.2	3.0	1.8	-3.2	1.8	4.8	-0.2	3.6	1.6

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	96	93-92	94-93	95-94	96-95	94-92	95-93	96-94	95-92	96-93	96-92
13073s	11	60.6	59.6	56.6	56.4	57.4	-1.0	-3.0	-0.2	1.0	-4.0	-3.2	0.8	-4.2	-2.2	-3.2
	11.5	57.4	53.4	52.8	55.0	59.6	-4.0	-0.6	2.2	4.6	-4.6	1.6	8.8	-2.4	6.2	2.2
	12	60.6	60.6	52.6	52.2	53.8	0.0	-8.0	-0.4	1.6	-8.0	-8.4	1.2	-8.4	-6.8	-6.8
	12.5	55.4	53.6	52.8	52.6	55.8	-1.8	-0.8	-0.2	3.0	-2.6	-1.0	2.8	-2.8	2.0	0.2
	13	54.8	54.2	55.0	58.8	58.4	-0.8	0.8	3.8	-0.4	0.2	4.8	3.4	4.0	4.2	3.6
	13.5	58.0	54.5	55.8	56.0	59.0	-3.5	1.3	2.3	1.0	-2.3	3.5	3.3	0.0	4.5	1.0
	14	50.4	49.4	50.8	53.8	52.8	-1.0	1.4	3.0	-1.0	0.4	4.4	2.0	3.4	3.4	2.4
	14.5	54.2	53.8	59.6	55.6	56.0	-0.6	6.0	-4.0	0.4	5.4	2.0	-3.8	1.4	2.4	1.8
	15	48.2	50.0	55.6	54.2	53.0	1.8	5.8	-1.4	-1.2	7.4	4.2	-2.8	6.0	3.0	4.8
	15.5	51.0	49.6	56.0	54.8	53.0	-1.2	8.2	-1.2	-1.8	5.0	5.0	-3.0	3.8	3.2	2.0
12033n	0	65.6	68.0	70.6	70.8	71.8	2.4	2.6	0.0	1.2	5.0	2.6	1.2	5.0	3.8	6.2
	0.5	64.0	65.0	66.2	68.4	68.8	1.0	1.2	2.2	0.4	2.2	3.4	2.6	4.4	3.8	4.8
	1	61.0	60.8	67.2	66.6	67.8	-0.2	6.4	-0.6	1.2	6.2	5.8	0.8	5.6	7.0	6.8
	1.5	59.2	56.6	63.2	56.8	63.0	-2.8	6.6	-4.4	4.2	4.0	2.2	-0.2	-0.4	6.4	3.8
	2	54.4	55.0	57.4	58.2	[illegible]	0.6	2.4	0.8	8.0	3.0	3.2	8.8	3.8	11.2	11.8
	2.5	57.8	57.8	60.2	65.2	68.0	0.0	2.4	5.0	0.8	2.4	7.4	5.8	7.4	8.2	8.2
	3	55.8	58.2	60.0	62.4	63.8	2.4	1.8	2.4	1.4	4.2	4.2	3.8	8.6	5.6	8.0
	3.5	57.6	57.8	60.2	65.2	68.0	0.2	2.4	5.0	2.8	2.6	7.4	7.8	7.6	10.2	10.4
	4	55.6	58.0	59.6	61.4	64.0	2.4	1.6	1.8	2.6	4.0	3.4	4.4	5.8	6.0	8.4
	4.5	64.2	65.8	66.6	68.8	69.4	1.6	0.8	2.0	0.6	2.4	2.8	2.8	4.4	3.6	5.2
	5	61.6	63.8	65.5	64.6	69.0	2.2	1.8	-0.9	4.4	3.9	0.8	3.5	3.0	5.3	7.4
	5.5	57.0	58.4	60.8	62.8	61.0	1.4	2.4	2.0	-1.8	3.8	4.4	0.2	5.8	2.6	4.0
	6	50.8	52.2	52.6	55.8	58.0	1.4	0.4	3.2	2.2	1.8	3.6	5.4	5.0	5.8	7.2
	6.5	51.2	53.4	56.8	61.4	58.4	2.2	3.4	4.6	-3.0	5.6	8.0	1.6	10.2	5.0	7.2
	7	49.2	51.8	55.2	61.0	61.6	2.8	3.4	5.8	0.6	6.0	9.2	6.4	11.8	9.8	12.4
	7.5	63.0	63.8	66.4	68.6	68.0	0.8	2.6	2.2	-0.8	3.4	4.8	1.8	5.6	4.2	5.0
	8	64.4	63.6	65.2	65.0	65.8	-0.8	1.6	-0.2	0.8	0.8	1.4	0.6	0.6	2.2	1.4
	8.5	65.8	67.2	69.0	68.4	71.8	1.4	1.8	-0.6	3.4	3.2	1.2	2.8	2.6	4.6	6.0
	9	69.0	69.4	68.8	68.8	70.2	0.4	-0.6	0.0	1.4	-0.2	-0.6	1.4	-0.2	0.8	1.2
	9.5	73.2	73.6	76.8	76.2	78.8	0.4	3.2	-0.6	2.8	3.6	2.6	2.0	3.0	5.2	5.6
	10	70.6	71.6	75.6	74.0	78.0	1.0	4.0	-1.8	4.0	5.0	2.4	2.4	3.4	6.4	7.4
	10.5	54.6	55.4	59.6	57.6	64.8	0.8	4.4	-2.2	7.2	5.2	2.2	5.0	3.0	9.4	10.2
	11	50.0	49.6	52.2	53.2	59.4	-0.4	2.6	1.0	6.2	2.2	3.6	7.2	3.2	9.8	9.4
	11.5	56.3	56.3	57.8	60.3	63.5	0.0	1.5	2.5	3.3	1.5	4.0	5.8	4.0	7.3	7.3
	12	65.0	67.5	85.3	68.3	66.3	2.5	-2.3	3.1	-2.0	0.3	0.8	1.1	3.3	-1.2	1.3
12033s	0	72.0	72.2	74.8	74.4	76.4	0.2	2.8	-0.4	2.0	2.8	2.2	1.6	2.4	4.2	4.4
	0.5	68.0	67.2	68.2	70.0	71.6	-0.8	1.0	1.8	1.6	0.2	2.8	3.4	2.0	4.4	3.6
	1	58.4	61.0	65.6	64.6	64.8	2.6	4.6	-1.0	0.2	7.2	3.6	-0.8	6.2	3.8	6.4
	1.5	51.8	58.2	58.2	61.8	57.8	6.4	0.0	3.6	-4.0	6.4	3.6	-0.4	10.0	-0.4	6.0
	2	54.6	55.8	60.2	59.2	58.6	1.2	4.4	-1.0	-0.6	5.6	3.4	-1.6	4.6	2.8	4.0
	2.5	59.4	58.6	64.2	64.0	62.8	-0.8	5.6	-0.2	-1.2	4.8	5.4	-1.4	4.6	4.2	3.4
	3	51.8	54.0	57.2	57.0	56.4	2.2	3.2	-0.2	-0.6	5.4	3.0	-0.8	5.2	2.4	4.6
	3.5	58.2	61.8	58.4	62.6	62.8	3.6	-3.4	4.2	0.2	0.2	0.8	4.4	4.4	1.0	4.6
	4	54.8	57.8	59.8	59.8	62.0	3.0	2.0	0.0	2.2	5.0	2.0	2.2	5.0	4.2	7.2
	4.5	66.0	66.0	66.4	68.6	67.2	0.0	0.4	2.2	-1.4	0.4	2.6	0.8	2.6	1.2	1.2

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	96	93-92	94-93	95-94	96-95	94-92	95-93	96-94	95-92	96-93	96-92
12033s	5	63.0	64.5	63.8	64.2	65.0	1.5	-0.9	0.6	0.8	0.6	-0.3	1.4	1.2	0.5	2.0
	5.5	55.0	58.2	59.3	61.3	62.0	3.2	1.1	2.0	0.8	4.3	3.1	2.8	6.3	3.8	7.0
	6	53.4	57.2	59.4	61.4	61.2	3.8	2.2	2.0	-0.2	6.0	4.2	1.8	8.0	4.0	7.8
	6.5	55.4	53.4	63.2	84.2	57.6	-2.0	9.8	1.0	-6.6	7.8	10.8	-5.6	8.8	4.2	2.2
	7	55.0	55.6	59.4	59.6	57.4	0.6	3.8	0.2	-2.2	4.4	4.0	-2.0	4.8	1.8	2.4
	7.5	59.0	59.0	66.6	65.0	64.0	0.0	7.6	-1.6	-1.0	7.6	6.0	-2.6	6.0	5.0	5.0
	8	62.2	63.2	67.4	69.6	70.4	1.0	4.2	2.2	0.8	5.2	6.4	3.0	7.4	7.2	8.2
	8.5	62.6	63.0	68.8	67.8	67.4	0.4	5.8	-1.0	-0.4	6.2	4.8	-1.4	5.2	4.4	4.8
	9	64.8	68.4	70.8	72.4	70.4	3.6	2.4	1.6	-2.0	6.0	4.0	-0.4	7.6	2.0	5.6
	9.5	69.2	73.2	73.0	75.0	74.6	4.0	-0.2	2.0	-0.4	3.8	1.8	1.6	5.8	1.4	5.4
	10	60.8	64.0	65.4	70.4	68.4	3.2	1.4	5.0	-2.0	4.6	6.4	3.0	9.6	4.4	7.6
	10.5	55.6	61.0	61.6	67.2	65.8	5.4	0.6	5.6	-1.4	6.0	8.2	4.2	11.8	4.8	10.2
	11	58.6	61.6	64.2	61.6	84.4	3.0	2.6	-2.8	2.8	5.8	0.0	0.2	3.0	2.8	5.8
	11.5	53.0	56.5	60.8	59.8	60.5	3.5	4.3	-1.1	0.8	7.8	3.3	-0.3	6.8	4.0	7.5
	12	55.3	56.8	62.0	56.7	60.0	1.5	5.3	-5.3	3.3	6.8	-0.1	-2.0	1.4	3.3	4.8
12034n	0	74.8	73.0	76.8	75.5	80.6	-1.6	3.8	-1.3	5.1	2.2	2.5	3.8	0.9	7.6	6.0
	0.5	66.8	68.4	69.6	71.6	76.2	1.6	1.2	2.0	4.6	2.8	3.2	6.6	4.8	7.8	9.4
	1	70.4	71.0	72.0	73.6	80.0	0.6	1.0	1.6	6.4	1.6	2.6	8.0	3.2	9.0	9.6
	1.5	65.6	66.6	67.2	70.2	72.2	1.0	0.6	3.0	2.0	1.6	3.8	5.0	4.8	5.6	6.6
	2	57.2	57.4	57.4	60.8	62.2	0.2	0.0	3.4	1.4	0.2	3.4	4.8	3.6	4.8	5.0
	2.5	69.4	70.4	76.4	74.6	73.2	1.0	6.0	-1.8	-1.4	7.0	4.2	-3.2	5.2	2.8	3.8
	3	71.6	73.2	73.8	74.4	74.8	1.6	0.6	0.6	0.2	2.2	1.2	0.8	2.8	1.4	3.0
	3.5	70.4	74.8	77.4	72.8	72.4	4.4	2.6	-4.8	-0.4	7.0	-2.0	-5.0	2.4	-2.4	2.0
	4	71.2	73.0	74.0	78.2	73.4	1.8	1.0	4.2	-4.8	2.8	5.2	-0.8	7.0	0.4	2.2
	4.5	70.8	73.0	76.8	78.0	73.6	2.4	3.8	1.2	-4.4	6.2	5.0	-3.2	7.4	0.6	3.0
	5	74.8	77.4	79.8	77.2	78.6	2.6	2.4	-2.6	-0.6	5.0	-0.2	-3.2	2.4	-0.8	1.8
	5.5	67.8	70.0	71.8	72.4	72.6	2.2	1.8	0.6	0.2	4.0	2.4	0.8	4.6	2.6	4.8
	6	75.4	74.6	76.0	76.6	79.8	-0.8	1.4	0.6	3.2	0.8	2.0	3.6	1.2	5.2	4.4
	6.5	64.8	67.5	73.5	71.0	70.5	2.8	6.0	-2.5	-0.5	8.8	3.5	-3.0	6.3	3.0	5.8
	7	69.4	70.8	71.4	73.2	74.8	1.4	0.6	1.8	1.6	2.0	2.4	3.4	3.8	4.0	5.4
	7.5	65.0	67.8	71.4	71.8	70.2	2.8	3.6	0.4	-1.6	6.4	4.0	-1.2	6.8	2.4	5.2
	8	69.4	74.6	75.6	75.8	71.4	5.2	1.0	0.2	-4.4	6.2	1.2	-4.2	6.4	-3.2	2.0
	8.5	63.0	67.0	69.4	71.2	68.4	4.0	2.4	1.8	-2.8	6.4	4.2	-1.0	8.2	1.4	5.4
	9	62.4	66.4	67.0	66.6	67.4	4.0	0.6	-0.4	0.8	4.6	0.2	0.4	4.2	1.0	5.0
12034s	0	72.4	74.2	73.0	73.0	73.6	1.8	-1.2	0.0	0.6	0.6	-1.2	0.6	0.6	-0.6	1.2
	0.5	68.2	68.4	72.0	72.2	74.2	0.2	3.6	0.2	2.0	3.8	3.8	2.2	4.0	5.8	6.0
	1	62.0	66.4	68.8	68.4	69.2	4.4	2.4	-0.4	0.8	6.8	2.0	0.4	6.4	2.8	7.2
	1.5	57.8	60.8	68.0	66.2	65.0	3.0	7.2	-1.8	-1.2	10.2	5.4	-3.0	8.4	4.2	7.2
	2	67.6	69.2	71.4	73.6	73.4	1.6	2.2	2.2	-0.2	3.8	4.4	2.0	8.0	4.2	5.8
	2.5	66.6	69.2	70.2	69.0	70.4	2.6	1.0	-1.2	1.4	3.6	-0.2	0.2	2.4	1.2	3.8
	3	70.2	72.4	74.0	74.0	75.2	2.2	1.6	0.0	1.2	3.8	1.6	1.2	3.8	2.8	5.0
	3.5	71.4	72.6	77.4		76.8	1.4	4.6			6.0		-0.6		4.0	5.4
	4	71.4	71.8	75.8	71.0	75.4	0.4	4.0	-4.8	4.4	4.4	-0.8	-0.4	-0.4	3.6	4.0
	4.5	68.6	68.8	74.0	71.0	74.0	0.2	5.2	-3.0	3.0	5.4	2.2	0.0	2.4	5.2	5.4
	5	68.0	69.8	73.0	71.0	73.6	1.8	3.2	-2.0	2.6	5.0	1.2	0.6	3.0	3.8	5.6

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	98	93-92	94-93	95-94	96-95	94-92	95-93	96-94	95-92	96-93	96-92
12034s	5.5	63.8	64.4	67.0	67.6	67.4	0.6	2.6	0.8	-0.2	3.2	3.2	0.4	3.8	3.0	3.6
	6	60.0	60.8	64.2	64.8	65.2	0.6	3.6	0.8	0.4	4.2	4.2	1.0	4.8	4.6	5.2
	6.5	85.3	66.5	74.8	67.3	71.7	1.3	8.3	-7.4	4.3	9.5	0.8	-3.1	2.1	5.2	6.4
	7	64.4	63.0	67.8	66.0	69.8	-1.4	4.8	-1.8	3.6	3.4	3.0	1.8	1.6	8.8	5.2
	7.5	59.4	60.4	67.4	61.2	65.8	1.0	7.0	-6.2	4.8	8.0	0.8	-1.6	1.8	5.4	6.4
	8	55.4	57.8	63.2	58.6	62.0	2.4	5.4	-4.8	3.4	7.8	0.8	-1.2	3.2	4.2	6.6
	8.5	60.0	59.4	65.8	81.6	87.2	-0.8	6.2	-4.0	5.8	5.6	2.2	1.6	1.8	7.8	7.2
	9	62.4	84.4	67.2	64.4	72.4	2.0	2.8	-2.8	8.0	4.8	0.0	5.2	2.0	8.0	10.0
50111e	0	64.0	65.8	64.6	71.8	N.A.	1.8	-1.2	7.2	N.A.	0.8	8.0	N.A.	7.8	N.A.	N.A.
	0.5	65.8	67.2	67.2	69.2	N.A.	1.4	0.0	2.0	N.A.	1.4	2.0	N.A.	3.4	N.A.	N.A.
	1	77.6	76.4	74.8	74.8	N.A.	-1.2	-1.8	-0.2	N.A.	-2.8	-1.8	N.A.	-3.0	N.A.	N.A.
	1.5	70.0	73.0	72.4	73.8	N.A.	3.0	-0.8	1.4	N.A.	2.4	0.8	N.A.	3.8	N.A.	N.A.
	2	72.8	74.0	72.4	73.4	N.A.	1.2	-1.6	1.0	N.A.	-0.4	-0.8	N.A.	0.6	N.A.	N.A.
	2.5	63.4	86.6	85.8	68.6	N.A.	3.2	-0.8	2.8	N.A.	2.4	2.0	N.A.	5.2	N.A.	N.A.
	3	75.2	74.4	78.6	77.2	N.A.	-0.8	4.2	-1.4	N.A.	3.4	2.8	N.A.	2.0	N.A.	N.A.
	3.5	76.0	73.2	78.6	78.6	N.A.	-2.8	5.4	0.0	N.A.	2.6	5.4	N.A.	2.8	N.A.	N.A.
	4	74.8	77.0	77.0	79.0	N.A.	2.2	0.0	2.0	N.A.	2.2	2.0	N.A.	4.2	N.A.	N.A.
	4.5	70.6	73.0	77.8	75.8	N.A.	2.4	4.6	-1.8	N.A.	7.0	2.8	N.A.	5.2	N.A.	N.A.
	5	74.0	78.8	79.3	74.3	N.A.	4.8	0.5	-5.0	N.A.	5.3	-4.5	N.A.	0.3	N.A.	N.A.
	5.5	69.0	72.0	71.3	73.8	N.A.	3.0	-0.8	2.5	N.A.	2.3	1.8	N.A.	4.8	N.A.	N.A.
33035n	0	51.2	53.6	55.2	57.2	57.6	2.4	1.6	2.0	0.4	4.0	3.6	2.4	6.0	4.0	6.4
	0.5	54.8	60.8	64.4	59.6	81.0	6.0	3.8	-4.8	1.4	9.6	-1.2	-3.4	4.8	0.2	6.2
	1	57.0	60.8	82.8	59.8	81.8	3.8	2.0	-3.0	1.8	5.8	-1.0	-1.2	2.8	0.8	4.6
	1.5	69.0	71.8	73.8	75.5	71.5	2.8	2.0	1.8	-4.0	4.8	3.8	-2.3	8.5	-0.3	2.5
	2	60.7	62.2	58.8	59.8	59.8	1.5	-3.4	1.0	0.0	-1.9	-2.4	1.0	-0.9	-2.4	-0.9
	2.5	55.5	60.0	57.5	58.5	58.8	4.5	-2.5	1.0	0.3	2.0	-1.5	1.3	3.0	-1.3	3.3
	3	54.2	56.4	63.0	58.6	57.0	2.2	8.8	-4.4	-1.6	8.8	2.2	-6.0	4.4	0.8	2.8
	3.5	59.8	59.8	60.8	62.4	63.2	0.0	1.0	1.6	0.8	1.0	2.8	2.4	2.6	3.4	3.4
	4	61.5	62.8	63.3	63.0	60.7	1.3	0.5	-0.3	-2.3	1.8	0.3	-2.8	1.5	-2.1	-0.8
	4.5	56.8	61.4	60.4	60.4	60.0	4.6	-1.0	0.0	-0.4	3.6	-1.0	-0.4	3.6	-1.4	3.2
	5	56.6	81.0	65.0	81.2	83.8	4.4	4.0	-3.8	2.4	8.4	0.2	-1.4	4.6	2.6	7.0
	5.5	62.3	64.3	64.8	65.0	66.3	2.0	0.5	0.3	1.3	2.5	0.8	1.5	2.8	2.0	4.0
	6	67.0	69.5	73.0	73.5	71.5	2.5	3.5	0.5	-2.0	6.0	4.0	-1.5	6.5	2.0	4.5
41029n	2	N.A.	76.0	80.5	78.0	73.0	N.A.	4.5	-2.5	-5.0	N.A.	2.0	-7.5	N.A.	-3.0	N.A.
	2.5	N.A.	63.6	65.8	68.0	64.8	N.A.	2.2	2.2	-3.2	N.A.	4.4	-1.0	N.A.	1.2	N.A.
	3	N.A.	62.0	65.0	67.3	66.5	N.A.	3.0	2.3	-0.8	N.A.	5.3	1.5	N.A.	4.5	N.A.
	3.5	N.A.	60.6	64.4	69.0	67.6	N.A.	3.8	4.6	-1.4	N.A.	8.4	3.2	N.A.	7.0	N.A.
	4	N.A.	64.5	65.0	66.0	64.8	N.A.	0.5	1.0	-1.3	N.A.	1.5	-0.3	N.A.	0.3	N.A.
	4.5	N.A.	61.8	61.4	68.8	68.2	N.A.	-0.4	7.4	-2.6	N.A.	7.0	4.8	N.A.	4.4	N.A.
	5	N.A.	61.4	59.0	63.0	66.4	N.A.	-2.4	4.0	3.4	N.A.	1.6	7.4	N.A.	5.0	N.A.
	5.5	N.A.	61.3	63.8	64.0	60.7	N.A.	2.5	0.3	-3.3	N.A.	2.8	-3.1	N.A.	-0.6	N.A.
	6	N.A.	65.8	66.2	86.2	67.4	N.A.	0.4	0.0	1.2	N.A.	0.4	1.2	N.A.	1.6	N.A.
	6.5	N.A.	64.8	68.3	64.3	72.0	N.A.	3.5	-3.9	7.7	N.A.	-0.4	3.8	N.A.	7.3	N.A.
	7	N.A.	55.8	55.7	60.0	67.0	N.A.	-0.1	4.3	7.0	N.A.	4.3	11.3	N.A.	11.3	N.A.
	7.5	N.A.	71.3	72.0	75.5	78.3	N.A.	0.8	3.5	0.8	N.A.	4.3	4.3	N.A.	5.1	N.A.

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	96	93-92	94-93	95-94	96-95	94-92	95-93	96-94	95-92	96-93	96-92
	8	N.A.	70.3	76.3	63.0	76.0	N.A.	6.0	6.6	-7.0	N.A.	12.8	-0.3	N.A.	5.8	N.A.
	8.5	N.A.	86.0	70.0	71.0	78.7	N.A.	-16.0	1.0	7.7	N.A.	-15.0	8.7	N.A.	-7.3	N.A.
	9	N.A.	75.7	55.0	57.5	66.7	N.A.	-20.7	2.5	9.2	N.A.	-18.2	11.7	N.A.	-9.0	N.A.
41029s	2	N.A.	74.7	76.0	68.5	71.0	N.A.	1.3	-7.5	2.5	N.A.	-6.2	-5.0	N.A.	-3.7	N.A.
	2.5	N.A.	64.0	65.8	67.6	69.6	N.A.	1.8	1.8	2.0	N.A.	3.6	3.8	N.A.	5.6	N.A.
	3	N.A.	60.8	61.3	63.0	59.3	N.A.	0.5	1.6	-3.8	N.A.	2.3	-2.0	N.A.	-1.5	N.A.
	3.5	N.A.	60.6	60.2	62.6	65.2	N.A.	-0.4	2.4	2.6	N.A.	2.0	5.0	N.A.	4.6	N.A.
	4	N.A.	59.3	60.8	60.8	65.0	N.A.	1.5	0.0	4.2	N.A.	1.6	4.3	N.A.	5.8	N.A.
	4.5	N.A.	64.2	63.6	70.0	72.5	N.A.	-0.6	6.4	2.5	N.A.	5.8	8.9	N.A.	8.3	N.A.
	5	N.A.	66.8	64.2	65.8	72.0	N.A.	-2.6	1.6	8.2	N.A.	-1.0	7.8	N.A.	5.2	N.A.
	5.5	N.A.	64.5	64.0	58.5	65.0	N.A.	-0.5	-5.5	6.5	N.A.	-6.0	1.0	N.A.	0.5	N.A.
	6	N.A.	63.0	62.6	64.6	71.6	N.A.	-0.4	2.0	7.0	N.A.	1.8	9.0	N.A.	8.6	N.A.
	6.5	N.A.	62.3	63.3	67.3	65.0	N.A.	1.0	4.1	-2.3	N.A.	5.1	1.8	N.A.	2.8	N.A.
	7	N.A.	49.8	63.3	57.0	60.5	N.A.	13.5	-6.3	3.5	N.A.	7.3	-2.8	N.A.	10.8	N.A.
	7.5	N.A.	48.5	57.8	51.0	53.0	N.A.	9.3	-6.8	2.0	N.A.	2.5	-4.8	N.A.	4.5	N.A.
	8	N.A.	50.6	53.0	53.0	52.4	N.A.	2.4	0.0	-0.6	N.A.	2.4	-0.6	N.A.	1.8	N.A.
	8.5	N.A.	70.3	61.7	74.5	63.0	N.A.	-8.7	12.8	-11.5	N.A.	4.2	1.3	N.A.	-7.3	N.A.
	9	N.A.	59.0	43.3	81.0	61.3	N.A.	-15.7	17.7	0.3	N.A.	2.0	18.0	N.A.	2.3	N.A.
03034n	0	43.8	44.6	43.6	50.2	49.4	0.8	-1.0	6.6	-0.8	-0.2	5.6	5.8	6.4	4.8	5.6
	0.5	48.0	44.0	43.4	43.4	48.8	-4.0	-0.6	0.0	5.4	-4.6	-0.6	5.4	-4.6	4.8	0.8
	1	38.8	41.8	47.8	55.8	53.0	3.0	6.0	8.0	-2.8	9.0	14.0	5.2	17.0	11.2	14.2
	1.5	41.6	48.0	48.6	54.2	53.6	6.4	0.6	5.6	-0.6	7.0	6.2	5.0	12.6	5.6	12.0
	2	50.4	52.2	51.6	60.4	59.6	1.8	-0.6	8.8	-0.8	1.2	8.2	8.0	10.0	7.4	9.2
	2.5	60.4	63.2	67.2	68.6	70.4	2.8	4.0	1.4	1.8	6.8	5.4	3.2	8.2	7.2	10.0
	3	50.4	58.2	56.0	60.2	61.2	7.8	-2.2	4.2	1.0	5.6	2.0	5.2	9.8	3.0	10.8
	3.5	54.0	66.2	67.6	66.6	71.8	12.2	1.4	-1.0	5.2	13.6	0.4	4.2	12.6	5.6	17.8
	4	68.3	72.0	76.8	76.3	75.3	3.8	4.8	-0.4	-1.0	8.5	4.3	-1.4	8.1	3.3	7.1
	4.5	63.3	71.5	71.8	73.7	76.5	8.3	0.3	1.9	2.8	8.5	2.2	4.8	10.4	5.0	13.3
	5	70.0	75.6	71.8	74.4	76.4	5.6	-3.8	2.6	2.0	1.8	-1.2	4.6	4.4	0.8	6.4
	5.5	69.6	71.6	71.4	72.2	74.2	2.0	-0.2	0.8	2.0	1.8	0.6	2.8	2.6	2.6	4.6
	6	66.4	66.8	72.0	71.0	70.8	0.4	5.2	-1.0	-0.2	5.6	4.2	-1.2	4.6	4.0	4.4
	6.5	68.0	69.8	70.0	67.0	15.6	1.8	0.2	-3.0	-51.4	2.0	-2.8	-54.4	-1.0	-54.2	-52.4
03034s	0	34.8	36.6	36.8	39.0	39.8	1.8	0.2	2.2	0.8	2.0	2.4	3.0	4.2	3.2	5.0
	0.5	38.2	44.4	46.6	43.2	50.0	6.2	2.2	-3.4	6.8	8.4	-1.2	3.4	5.0	5.6	11.8
	1	41.8	43.8	44.8	42.4	43.8	2.0	1.0	-2.4	1.4	3.0	-1.4	-1.0	0.6	0.0	2.0
	1.5	46.0	47.6	51.4	53.6	52.0	1.6	3.8	2.2	-1.6	5.4	6.0	0.6	7.6	4.4	6.0
	2	59.8	62.0	58.0	62.0	66.6	2.2	-4.0	4.0	4.6	-1.8	0.0	8.6	2.2	4.6	6.8
	2.5	63.6	65.6	68.2	68.6	69.2	2.0	2.6	0.4	0.6	4.6	3.0	1.0	5.0	3.6	5.8
	3	63.0	68.2	71.8	69.4	68.6	5.2	3.6	-2.4	-0.8	8.8	1.2	-3.2	6.4	0.4	5.6
	3.5	69.6	74.2	72.0	72.8	73.6	4.6	-2.2	0.8	0.8	2.4	-1.4	1.8	3.2	-0.6	4.0
	4	68.8	68.8	69.0	73.7	73.3	0.0	0.3	4.7	-0.3	0.3	4.9	4.3	4.9	4.6	4.6
	4.5	66.5	70.3	71.0	67.0	69.5	3.8	0.8	-4.0	2.5	4.5	-3.3	-1.5	0.5	-0.8	3.0
	5	63.2	59.6	62.4	60.2	60.6	-3.6	2.8	-2.2	0.4	-0.8	0.6	-1.8	-3.0	1.0	-2.6
	5.5	59.4	59.2	63.4	60.4	62.4	-0.2	4.2	-3.0	2.0	4.0	1.2	-1.0	1.0	3.2	3.0
	6	62.2	62.2	63.4	59.4	63.0	0.0	1.2	-4.0	3.6	1.2	-2.8	-0.4	-2.8	0.8	0.8

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	96	93-92	94-93	95-94	98-95	94-92	95-93	98-94	95-92	96-93	96-92
	6.5	64.8	66.6	62.0	64.4	66.2	2.0	-4.6	2.4	1.8	-2.6	-2.2	4.2	-0.2	-0.4	1.6
17034n	0	48.4	47.6	55.8	59.0	57.8	1.2	8.2	3.2	-1.2	9.4	11.4	2.0	12.8	10.2	11.4
	0.5	58.2	58.8	88.4	63.0	63.8	0.6	7.8	-3.4	0.8	6.2	4.2	-2.8	4.8	4.8	5.4
	1	54.6	55.8	54.8	54.0	55.6	1.0	-0.8	-0.8	1.8	0.2	-1.8	1.0	-0.6	0.2	1.2
	1.5	55.4	51.4	52.2	54.8	57.0	-4.0	0.8	2.6	2.2	-3.2	3.4	4.6	-0.6	5.8	1.6
	2	58.0	53.8	54.2	58.8	55.8	-4.4	0.6	4.4	-2.6	-3.8	5.0	1.8	0.6	2.2	-2.2
	2.5	53.6	52.6	51.2	54.0	54.6	-1.0	-1.4	2.6	0.6	-2.4	1.4	3.4	0.4	2.0	1.0
	3	56.2	54.8	54.6	55.4	56.8	-1.4	0.0	0.8	3.4	-1.4	0.6	4.0	-0.8	4.0	2.6
	3.5	51.4	48.8	49.6	51.8	51.2	-2.6	0.8	2.2	-0.8	-1.8	3.0	1.6	0.4	2.4	-0.2
	4	46.8	45.4	47.8	49.2	51.0	-1.4	2.4	1.4	1.8	1.0	3.8	3.2	2.4	5.6	4.2
	4.5	61.8	58.6	59.6	59.8	60.4	-3.0	1.0	0.2	0.6	-2.0	1.2	0.8	-1.8	1.8	-1.2
	5	54.2	52.6	53.6	56.6	53.4	-1.8	1.0	3.0	-3.2	-0.8	4.0	-0.2	2.4	0.6	-0.8
	5.5	51.6	51.0	51.6	55.8	53.4	-0.6	0.6	4.2	-2.4	0.0	4.8	1.6	4.2	2.4	1.8
	6	52.2	52.8	58.6	55.2	53.0	0.6	5.8	-3.4	-2.2	6.4	2.4	-5.6	3.0	0.2	0.8
	6.5	53.4	56.2	58.8	61.0	57.2	2.8	2.6	2.2	-3.8	5.4	4.8	-1.6	7.6	1.0	3.8
	7	57.8	60.6	61.2	63.4	63.8	2.8	0.6	2.2	0.4	3.4	2.8	2.6	5.6	3.2	6.0
	7.5	70.8	68.4	71.4	68.8	68.8	-2.4	3.0	-2.8	0.0	0.6	0.4	-2.6	-2.0	0.4	-2.0
	8	52.6	52.2	58.6	56.4	61.0	-0.4	6.4	-2.2	4.8	6.0	4.2	2.4	3.8	8.8	8.4
	8.5	67.5	64.4	64.8	83.3	N.A.	-3.1	0.4	-1.6	N.A.	-2.7	-1.2	N.A.	-4.3	N.A.	N.A.
17034s	0	46.2	50.0	55.2	57.2	53.8	3.8	5.2	2.0	-3.4	9.0	7.2	-1.4	11.0	3.8	7.6
	0.5	63.0	61.8	66.4	74.2	67.0	-1.2	4.6	7.8	-7.2	3.4	12.4	0.6	11.2	5.2	4.0
	1	51.6	51.8	52.8	54.4	56.4	0.0	1.0	1.6	2.0	1.0	2.6	3.6	2.6	4.6	4.6
	1.5	54.2	53.2	54.8	56.0	57.0	-1.0	1.6	1.2	1.0	0.6	2.8	2.2	1.8	3.8	2.8
	2	59.6	62.4	62.6	63.0	65.8	2.8	0.2	0.4	2.8	3.0	0.6	3.2	3.4	3.4	6.2
	2.5	56.4	55.6	57.2	58.0	56.8	-0.8	1.6	0.8	-1.2	0.8	2.4	-0.4	1.8	1.2	0.4
	3	53.0	58.0	60.0	59.8	60.0	5.0	2.0	-0.2	0.2	7.0	1.8	0.0	6.8	2.0	7.0
	3.5	55.4	55.4	57.2	57.8	60.6	0.0	1.8	0.8	2.6	1.8	2.4	3.4	2.4	5.2	5.2
	4	52.2	54.2	57.6	53.6	54.4	2.0	3.4	-4.0	0.8	5.4	-0.6	-3.2	1.4	0.2	2.2
	4.5	56.6	57.2	58.8	58.6	80.2	0.6	1.6	-0.2	1.8	2.2	1.4	1.4	2.0	3.0	3.6
	5	56.0	55.0	55.8	57.4	59.8	-1.0	0.8	1.8	2.4	-0.2	2.4	4.0	1.4	4.8	3.8
	5.5	52.8	50.8	54.8	53.8	56.2	-2.0	4.0	-1.0	2.4	2.0	3.0	1.4	1.0	5.4	3.4
	6	62.6	63.0	86.6	64.8	68.6	0.4	3.6	-1.8	3.8	4.0	1.8	2.0	2.2	5.6	6.0
	6.5	55.0	56.0	56.8	58.4	57.8	1.0	0.8	1.6	-0.6	1.8	2.4	1.0	3.4	1.8	2.8
	7	55.4	55.8	64.6	63.6	64.8	0.4	8.8	-1.0	1.2	9.2	7.8	0.2	8.2	9.0	9.4
	7.5	66.6	66.0	70.6	75.0	89.8	-0.6	4.6	4.4	-5.2	4.0	9.0	-0.8	8.4	3.6	3.2
	8	55.2	53.4	55.4	58.0	57.2	-1.8	2.0	2.6	-0.8	0.2	4.6	1.8	2.8	3.8	2.0
	8.5	81.2	75.4	74.6	71.7	N.A.	-5.8	-0.8	-2.9	N.A.	-6.6	-3.7	N.A.	-9.5	N.A.	N.A.
03033n	0	52.4	57.4	64.7	57.0	57.0	5.0	7.3	-7.7	0.0	12.3	-0.4	-7.7	4.6	-0.4	4.6
	0.5	59.0	58.2	59.2	60.6	66.2	-0.8	1.0	1.4	5.6	0.2	2.4	7.0	1.6	8.0	7.2
	1	56.4	53.8	56.0	58.2	58.4	-2.8	2.4	2.2	0.2	-0.4	4.6	2.4	1.8	4.8	2.0
	1.5	66.6	65.6	89.4	70.0	66.8	-1.0	3.8	0.6	-3.2	2.8	4.4	-2.8	3.4	1.2	0.2
	2	57.2	59.2	59.6	60.0	61.0	2.0	0.4	0.4	1.0	2.4	0.8	1.4	2.8	1.8	3.8
	2.5	58.3	80.5	57.8	59.3	64.7	2.3	-2.8	1.5	5.4	-0.5	-1.3	6.9	1.0	4.2	6.4
	3	47.2	48.2	56.8	65.6	55.0	1.0	8.6	8.8	-10.6	9.6	17.4	-1.8	18.4	6.8	7.8
	3.5	54.8	53.6	55.2	62.2	60.2	-1.2	1.6	7.0	-2.0	0.4	8.6	5.0	7.4	6.6	5.4

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	96	93-92	94-93	95-94	98-95	94-92	95-93	96-94	95-92	98-93	96-92
03033n	4	62.8	88.8	71.8	73.8	71.2	6.0	3.0	2.0	-2.6	9.0	5.0	-0.6	11.0	2.4	8.4
	4.5	65.2	72.4	69.4	71.4	71.2	7.2	-3.0	2.0	-0.2	4.2	-1.0	1.8	6.2	-1.2	6.0
	5	71.6	71.4	71.2	72.6	72.6	-0.2	-0.2	1.4	0.0	-0.4	1.2	1.4	1.0	1.2	1.0
	5.5	67.8	69.0	71.4	87.8	70.8	1.4	2.4	-3.6	3.0	3.8	-1.2	-0.6	0.2	1.8	3.2
	8	69.2	69.8	72.0	71.2	71.0	0.6	2.2	-0.8	-0.2	2.8	1.4	-1.0	2.0	1.2	1.8
	6.5	65.2	67.8	70.0	66.6	68.4	2.6	2.2	-3.4	1.8	4.8	-1.2	-1.6	1.4	0.6	3.2
	7	65.0	66.4	67.8	69.8	69.0	1.4	1.4	2.0	-0.8	2.8	3.4	1.2	4.8	2.6	4.0
	7.5	66.8	66.8	70.2	72.4	70.8	0.0	3.4	2.2	-1.6	3.4	5.8	0.6	5.6	4.0	4.0
	8	68.6	89.4	72.8	65.8	72.4	0.8	3.4	-7.0	6.8	4.2	-3.6	-0.4	-2.8	3.0	3.8
	8.5	55.2	57.4	59.8	70.8	65.0	2.2	2.4	11.0	-5.8	4.6	13.4	5.2	15.6	7.6	9.8
	9	66.8	66.6	67.4	66.0	70.0	-0.2	0.8	-1.4	4.0	0.6	-0.8	2.6	-0.8	3.4	3.2
	9.5	54.6	55.2	57.6	60.0	61.8	0.6	2.4	2.4	1.8	3.0	4.8	4.2	5.4	6.6	7.2
	10	54.0	51.0	56.0	63.2	56.6	-3.0	5.0	7.2	-6.6	2.0	12.2	0.6	9.2	5.6	2.6
	10.5	57.6	62.0	59.8	63.8	69.0	4.4	-2.2	4.0	5.2	2.2	1.8	9.2	6.2	7.0	11.4
	11	47.4	52.0	53.6	52.4	81.0	4.6	1.6	-1.2	8.8	8.2	0.4	7.4	5.0	9.0	13.6
	11.5	43.4	51.0	48.6	52.4	56.6	7.6	-2.4	3.8	4.2	5.2	1.4	8.0	9.0	5.6	13.2
	12	45.6	42.6	40.6	51.4	50.4	-3.0	-2.0	10.6	-1.0	-5.0	8.8	9.8	5.8	7.8	4.8
03033s	0.5	N.A.	48.6	47.4	50.0	50.0	N.A.	-1.2	2.6	0.0	N.A.	1.4	2.6	N.A.	1.4	N.A.
	1	N.A.	55.8	59.8	59.0	60.2	N.A.	4.0	-0.6	1.2	N.A.	3.2	0.4	N.A.	4.4	N.A.
	1.5	N.A.	61.6	65.0	63.8	65.4	N.A.	3.4	-1.2	1.6	N.A.	2.2	0.4	N.A.	3.8	N.A.
	2	N.A.	51.4	56.6	56.2	59.8	N.A.	5.2	-0.4	3.6	N.A.	4.6	3.2	N.A.	8.4	N.A.
	2.5	N.A.	59.5	58.0	58.8	54.8	N.A.	-1.5	-1.3	-2.0	N.A.	-2.8	-3.3	N.A.	-4.8	N.A.
	3	N.A.	54.0	53.4	59.2	55.0	N.A.	-0.6	5.8	-4.2	N.A.	5.2	1.6	N.A.	1.0	N.A.
	3.5	N.A.	64.4	60.6	62.6	66.0	N.A.	-3.8	2.0	3.4	N.A.	-1.8	5.4	N.A.	1.6	N.A.
	4	N.A.	53.2	53.4	56.4	55.8	N.A.	0.2	3.0	-0.6	N.A.	3.2	2.4	N.A.	2.6	N.A.
	4.5	N.A.	61.8	60.4	60.6	62.0	N.A.	-1.4	0.2	1.4	N.A.	-1.2	1.6	N.A.	0.2	N.A.
	5	N.A.	61.6	62.2	62.4	63.4	N.A.	0.4	0.2	1.0	N.A.	0.8	1.2	N.A.	1.6	N.A.
	5.5	N.A.	68.6	63.0	64.0	63.8	N.A.	-5.6	1.0	-0.2	N.A.	-4.6	0.6	N.A.	-4.8	N.A.
	6	N.A.	64.0	62.6	66.2	64.8	N.A.	-1.4	3.6	-1.4	N.A.	2.2	2.2	N.A.	0.8	N.A.
	6.5	N.A.	60.0	57.6	62.0	59.6	N.A.	-2.4	4.4	-2.4	N.A.	2.0	2.0	N.A.	-0.4	N.A.
	7	N.A.	63.2	62.6	65.4	66.0	N.A.	-0.8	2.8	0.6	N.A.	2.2	3.4	N.A.	2.8	N.A.
	7.5	N.A.	66.6	63.4	64.6	85.8	N.A.	-3.2	1.2	1.2	N.A.	-2.0	2.4	N.A.	-0.8	N.A.
	8	N.A.	63.6	70.4	70.2	70.0	N.A.	6.8	-0.2	-0.2	N.A.	6.6	-0.4	N.A.	6.4	N.A.
	8.5	N.A.	52.6	55.4	55.6	54.6	N.A.	2.8	0.2	-1.0	N.A.	3.0	-0.8	N.A.	2.0	N.A.
	9	N.A.	54.6	57.8	55.4	60.4	N.A.	3.2	-2.4	5.0	N.A.	0.8	2.6	N.A.	5.8	N.A.
	9.5	N.A.	55.0	60.4	60.0	59.2	N.A.	5.4	-0.4	-0.8	N.A.	5.0	-1.2	N.A.	4.2	N.A.
	10	N.A.	55.0	60.6	64.0	56.6	N.A.	5.6	3.4	-7.2	N.A.	9.0	-3.8	N.A.	1.8	N.A.
	10.5	N.A.	47.0	49.0	50.6	53.0	N.A.	2.0	1.6	2.4	N.A.	3.6	4.0	N.A.	6.0	N.A.
	11	N.A.	46.2	46.2	45.8	48.4	N.A.	0.0	-0.4	0.6	N.A.	-0.4	0.2	N.A.	0.2	N.A.
	11.5	N.A.	47.2	56.4	53.8	58.6	N.A.	9.2	-2.8	2.8	N.A.	8.6	0.2	N.A.	9.4	N.A.
	12	N.A.	36.2	37.4	41.0	41.8	N.A.	1.2	3.6	0.6	N.A.	4.6	4.2	N.A.	5.4	N.A.
39013n	0	64.0	62.6	61.2	60.2	61.6	-1.4	-1.4	-1.0	1.4	-2.8	-2.4	0.4	-3.8	-1.0	-2.4
	0.5	66.0	69.0	60.6	60.6	66.8	3.0	-8.4	0.0	6.2	-5.4	-8.4	6.2	-5.4	-2.2	0.8
	1	59.2	64.8	58.2	59.4	66.4	5.6	-6.6	1.2	7.0	-1.0	-5.4	8.2	0.2	1.6	7.2
	1.5	57.2	59.0	51.8	55.4	80.6	1.8	-7.2	3.6	5.2	-5.4	-3.6	8.8	-1.8	1.6	3.4

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rete
		92	93	94	95	96	93-92	94-93	95-94	96-95	94-92	95-93	96-94	95-92	96-93	96-92
39013n	2	82.2	73.4	80.0	62.8	65.6	11.2	-13.4	2.6	3.0	-2.2	-10.8	5.8	0.4	-7.8	3.4
	2.5	83.8	71.2	58.6	65.2	71.2	7.4	-14.8	8.8	6.0	-7.2	-6.0	14.8	1.4	0.0	7.4
	3	81.4	69.4	58.0	62.8	67.6	8.0	-11.4	4.8	5.0	-3.4	-6.8	9.6	1.2	-1.8	6.2
	3.5	60.8	62.2	62.4	59.0	81.8	1.6	0.2	-3.4	2.8	1.8	-3.2	-0.6	-1.6	-0.4	1.2
	4	62.4	67.0	65.0	59.8	64.8	4.6	-2.0	-5.4	5.2	2.8	-7.4	-0.2	-2.8	-2.2	2.4
	4.5	61.2	84.4	67.8	56.8	58.2	3.2	3.4	-11.0	1.4	6.8	-7.8	-9.6	-4.4	-8.2	-3.0
	5	62.8	64.6	82.4	58.6	58.4	1.8	-2.2	-5.8	-0.2	-0.4	-8.0	-6.0	-6.2	-8.2	-6.4
	5.5	59.0	59.8	63.4	58.6	58.2	0.8	3.6	-8.8	1.8	4.4	-3.2	-5.2	-2.4	-1.6	-0.8
	6	60.2	61.8	66.0	59.4	62.8	1.6	4.2	-6.8	3.4	5.8	-2.4	-3.2	-0.8	1.0	2.6
39014n1	0	67.8	72.4	79.4	71.0	73.8	4.8	7.0	-8.4	2.8	11.8	-1.4	-5.6	3.4	1.4	6.2
	0.5	71.8	74.0	75.6	76.6	77.2	2.2	1.8	1.0	0.8	3.8	2.8	1.6	4.8	3.2	5.4
	1	89.2	70.6	76.4	77.8	77.2	1.4	5.8	1.4	-0.8	7.2	7.2	0.8	8.6	8.6	8.0
	1.5	70.2	72.6	69.8	73.8	73.0	2.4	-2.8	4.0	-0.8	-0.4	1.2	3.2	3.6	0.4	2.8
	2	69.8	72.8	74.8	77.2	76.0	3.0	2.0	2.4	-1.2	5.0	4.4	1.2	7.4	3.2	6.2
	2.5	87.5	67.8	73.5	72.5	89.5	0.3	5.8	-1.0	-3.0	6.0	4.8	-4.0	5.0	1.8	2.0
	3	66.6	70.4	68.2	68.5	88.3	3.8	-2.2	-1.7	-0.3	1.6	-3.9	-2.0	-0.1	-4.2	-0.3
	3.5	67.0	71.4	68.8	68.0	69.2	4.4	-2.6	-0.6	1.2	1.8	-3.4	0.4	1.0	-2.2	2.2
50112e	0	77.2	78.0	77.6	79.2	N.A.	0.8	-0.4	1.8	N.A.	0.4	1.2	N.A.	2.0	N.A.	N.A.
	0.5	78.4	76.8	79.0	79.2	N.A.	-1.6	2.2	0.2	N.A.	0.8	2.4	N.A.	0.8	N.A.	N.A.
	1	78.4	79.8	82.0	80.8	N.A.	1.4	2.2	-1.2	N.A.	3.8	1.0	N.A.	2.4	N.A.	N.A.
	1.5	77.6	83.0	84.8	82.8	N.A.	5.4	1.8	-2.0	N.A.	7.2	-0.2	N.A.	5.2	N.A.	N.A.
	2	76.8	78.6	82.2	83.2	N.A.	2.0	3.8	1.0	N.A.	5.6	4.8	N.A.	6.6	N.A.	N.A.
	2.5	79.0	84.2	88.0	86.6	N.A.	5.2	1.6	0.6	N.A.	7.0	2.4	N.A.	7.6	N.A.	N.A.
	3	74.6	78.0	78.4	79.2	N.A.	3.4	0.4	0.8	N.A.	3.8	1.2	N.A.	4.6	N.A.	N.A.
	3.5	73.5	79.0	80.3	78.5	N.A.	5.5	1.3	-3.8	N.A.	6.8	-2.5	N.A.	3.0	N.A.	N.A.
	4	78.2	79.6	79.6	78.0	N.A.	1.4	0.0	-1.6	N.A.	1.4	-1.6	N.A.	-0.2	N.A.	N.A.
	4.5	71.4	74.2	71.8	73.2	N.A.	2.8	-2.4	1.4	N.A.	0.4	-1.0	N.A.	1.8	N.A.	N.A.
	5	73.8	75.4	76.0	72.2	N.A.	1.6	0.6	-3.8	N.A.	2.2	-3.2	N.A.	-1.6	N.A.	N.A.
	5.5	80.4	80.0	81.0	83.0	N.A.	-0.4	1.0	2.0	N.A.	0.6	3.0	N.A.	2.8	N.A.	N.A.
50112w	0	72.8	77.8	76.8	75.4	N.A.	5.0	-1.0	-1.2	N.A.	4.0	-2.2	N.A.	2.8	N.A.	N.A.
	0.5	72.4	77.2	78.2	76.0	N.A.	4.8	1.0	-2.2	N.A.	5.8	-1.2	N.A.	3.6	N.A.	N.A.
	1	78.8	80.6	77.8	78.0	N.A.	1.8	-2.8	0.2	N.A.	-1.0	-2.6	N.A.	-0.8	N.A.	N.A.
	1.5	73.8	73.8	78.2	73.4	N.A.	0.0	4.4	-4.8	N.A.	4.4	-0.4	N.A.	-0.4	N.A.	N.A.
	2	69.4	74.6	73.8	73.4	N.A.	5.2	-1.0	-0.2	N.A.	4.2	-1.2	N.A.	4.0	N.A.	N.A.
	2.5	70.6	74.8	77.4	72.0	N.A.	4.2	2.6	-5.4	N.A.	6.8	-2.8	N.A.	1.4	N.A.	N.A.
	3	75.8	77.0	78.8	77.8	N.A.	1.2	1.8	-1.0	N.A.	3.0	0.8	N.A.	2.0	N.A.	N.A.
	3.5	79.5	83.8	82.0	80.8	N.A.	4.3	-1.8	-1.3	N.A.	2.5	-3.0	N.A.	1.3	N.A.	N.A.
	4	75.0	82.0	82.2	78.6	N.A.	7.0	0.2	-3.8	N.A.	7.2	-3.4	N.A.	3.6	N.A.	N.A.
	4.5	75.4	77.2	80.0	74.4	N.A.	1.8	2.8	-5.6	N.A.	4.6	-2.8	N.A.	-1.0	N.A.	N.A.
	5	75.4	76.8	78.6	77.0	N.A.	1.4	-0.2	0.4	N.A.	1.2	0.2	N.A.	1.6	N.A.	N.A.
	5.5	83.4	86.4	83.6	85.8	N.A.	3.0	-2.8	2.2	N.A.	0.2	-0.6	N.A.	2.4	N.A.	N.A.
39014n2	4.5	70.8	73.4	76.2	71.2	72.4	2.8	2.8	-5.0	1.2	5.6	-2.2	-3.8	0.6	-1.0	1.8
	5	69.8	73.0	73.2	69.6	69.0	3.2	0.2	-3.6	-0.6	3.4	-3.4	-4.2	-0.2	-4.0	-0.8
	5.5	70.0	68.2	71.2	66.4	71.0	-1.8	3.0	-4.8	4.8	1.2	-1.8	-0.2	-3.6	2.8	1.0
	6	65.0	64.2	68.4	60.6	64.6	-0.8	4.2	-7.8	4.0	3.4	-3.6	-3.8	-4.4	0.4	-0.4

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	96	93-92	94-93	95-94	96-95	94-92	95-93	96-94	95-92	96-93	96-92
39014n2	6.5	62.8	63.2	66.8	82.2	66.4	0.4	3.8	-4.6	4.2	4.0	-1.0	-0.4	-0.8	3.2	3.6
	7	67.0	70.6	69.6	66.0	67.4	3.6	-1.0	-3.6	1.4	2.6	-4.6	-2.2	-1.0	-3.2	0.4
	7.5	59.4	62.2	60.4	58.6	60.2	2.8	-1.8	-1.8	1.6	1.0	-3.6	-0.2	-0.8	-2.0	0.8
	8	67.4	68.6	69.4	68.0	69.2	1.2	0.8	-1.4	1.2	2.0	-0.6	-0.2	0.6	0.6	1.8
	8.5	57.8	57.6	59.8	57.2	59.6	-0.2	2.2	-2.8	2.4	2.0	-0.4	-0.2	-0.6	2.0	1.8
	9	53.6	57.0	56.6	59.2	58.8	3.4	-0.4	2.6	-0.4	3.0	2.2	2.2	5.6	1.8	5.2
	9.5	60.5	66.8	65.5	62.7	59.7	6.3	-1.3	-2.8	-3.0	5.0	-4.1	-5.8	2.2	-7.1	-0.8
	10	60.8	62.0	83.4	66.8	86.8	1.2	1.4	3.4	0.0	2.6	4.8	3.4	6.0	4.8	6.0
	10.5	66.4	68.4	73.8	68.6	71.6	2.0	5.4	-5.2	3.0	7.4	0.2	-2.2	2.2	3.2	5.2
	11	61.4	60.0	62.8	62.6	62.8	-1.4	2.8	-0.2	0.2	1.4	2.6	0.0	1.2	2.8	1.4
	11.5	64.6	67.4	66.2	63.8	65.2	2.8	-1.2	-2.4	1.4	1.6	-3.6	-1.0	-0.6	-2.2	0.6
	12	59.0	63.2	62.4	59.4	62.0	4.2	-0.8	-3.0	2.8	3.4	-3.8	-0.4	0.4	-1.2	3.0
	12.5	63.8	63.6	66.0	62.2	65.0	-0.2	2.4	-3.8	2.8	2.2	-1.4	-1.0	-1.8	1.4	1.2
23152e	0	64.8	66.5	65.0	67.0	67.0	1.8	-1.5	2.0	0.0	0.3	0.5	2.0	2.3	0.5	2.3
	0.5	65.0	71.8	65.4	71.8	71.6	6.8	-6.4	6.4	-0.2	0.4	0.0	6.2	6.8	-0.2	6.6
	1	64.0	68.4	64.0	74.4	71.6	4.4	-4.4	10.4	-2.8	0.0	6.0	7.6	10.4	3.2	7.6
	1.5	64.5	72.3	67.3	75.8	76.3	7.8	-5.0	8.5	0.5	2.8	3.5	9.0	11.3	4.0	11.8
	2	66.4	65.8	70.0	66.3	66.5	-0.6	4.2	-3.8	0.3	3.6	0.5	-3.5	-0.2	0.7	0.1
	2.5	55.6	55.2	54.6	58.0	61.0	-0.4	-0.6	3.4	3.0	-1.0	2.8	6.4	2.4	5.8	5.4
	3	54.6	59.6	55.6	61.6	62.8	5.0	-4.0	6.0	1.2	1.0	2.0	7.2	7.0	3.2	8.2
	3.5	51.4	55.2	56.0	61.4	63.4	3.8	0.6	5.4	2.0	4.6	6.2	7.4	10.0	8.2	12.0
	4	56.2	60.0	59.0	70.6	72.8	3.8	-1.0	11.6	2.2	2.8	10.6	13.8	14.4	12.8	16.6
	4.5	52.0	59.0	53.0	63.6	70.4	7.0	-6.0	10.6	6.8	1.0	4.6	17.4	11.6	11.4	18.4
	5	53.2	54.6	52.4	57.4	64.2	1.4	-2.2	5.0	6.8	-0.8	2.8	11.8	4.2	9.6	11.0
	5.5	56.8	58.0	59.0	80.8	65.6	1.2	1.0	1.8	4.8	2.2	2.8	6.6	4.0	7.6	8.8
	6	50.3	49.7	53.3	55.7	60.7	-0.7	3.7	2.3	5.0	3.0	6.0	7.3	5.3	11.0	10.3
23152w	0	64.0	65.8	67.3	70.3	70.5	1.8	1.5	3.1	0.2	3.3	4.6	3.3	6.3	4.8	6.5
	0.5	63.0	65.8	66.8	68.6	73.8	2.8	1.0	1.8	5.2	3.8	2.8	7.0	5.6	8.0	10.8
	1	61.6	61.0	64.0	65.6	72.6	-0.6	3.0	1.6	7.0	2.4	4.6	8.6	4.0	11.6	11.0
	1.5	59.3	N.A.	64.3	73.3	73.3	N.A.	N.A.	9.0	0.0	5.0	N.A.	9.0	14.0	N.A.	14.0
	2	63.0	N.A.	71.4	71.8	75.3	N.A.	N.A.	0.3	3.5	8.4	N.A.	3.8	8.8	N.A.	12.3
	2.5	66.2	68.0	67.6	70.6	71.8	1.8	-0.4	3.0	1.2	1.4	2.6	4.2	4.4	3.8	5.6
	3	60.4	61.6	55.8	59.4	63.8	1.2	-5.8	3.6	4.4	-4.6	-2.2	8.0	-1.0	2.2	3.4
	3.5	60.8	61.4	63.4	69.6	73.6	0.8	2.0	6.2	4.0	2.7	8.2	10.2	8.8	12.2	12.9
	4	44.8	53.2	56.2	57.2	60.4	8.4	3.0	1.0	3.2	11.4	4.0	4.2	12.4	7.2	15.6
	4.5	49.8	55.8	54.0	57.4	58.2	6.0	-1.8	3.4	0.8	4.2	1.6	4.2	7.6	2.4	8.4
	5	56.6	59.2	58.6	59.8	63.4	2.6	-0.6	1.2	3.6	2.0	0.6	4.8	3.2	4.2	6.8
	5.5	65.6	60.3	60.3	59.8	62.8	-5.3	0.0	-0.5	3.1	-5.3	-0.5	2.6	-5.8	2.6	-2.8
	6	51.7	59.0	59.5	54.5	54.7	7.3	0.5	-5.0	0.2	7.8	-4.5	-4.8	2.8	-4.3	3.0
47066e	0	66.5	68.5	69.3	72.3	74.3	2.0	0.8	3.0	2.0	2.8	3.8	5.0	5.8	5.8	7.8
	0.5	57.6	59.4	62.4	66.0	70.0	1.8	3.0	3.8	4.0	4.8	6.6	7.6	8.4	10.6	12.4
	1	52.2	54.6	56.2	56.8	62.2	2.4	1.6	0.6	5.4	4.0	2.2	6.0	4.6	7.6	10.0
	1.5	58.0	60.8	62.2	65.6	74.6	2.8	1.4	3.4	9.0	4.2	4.8	12.4	7.6	13.8	16.6
	2	56.4	58.6	64.2	65.6	72.0	2.2	5.6	1.4	8.4	7.6	7.0	7.8	9.2	13.4	15.6
	2.5	55.8	58.4	62.0	60.2	66.2	2.6	3.6	-1.8	6.0	6.2	1.8	4.2	4.4	7.8	10.4

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	96	93-92	94-93	95-94	96-95	94-92	95-93	96-94	95-92	96-93	96-92
47066e	3	56.5	59.0	80.5	60.3	63.0	2.5	1.5	-0.3	2.6	4.0	1.3	2.5	3.8	4.0	6.5
	3.5	62.6	63.6	63.8	66.2	69.4	1.0	0.2	2.4	3.2	1.2	2.6	5.6	3.6	5.8	6.8
	4	69.0	69.2	71.4	73.4	76.6	0.2	2.2	2.0	3.2	2.4	4.2	5.2	4.4	7.4	7.6
	4.5	60.0	62.4	62.4	64.6	65.6	2.4	0.0	2.2	1.0	2.4	2.2	3.2	4.6	3.2	5.6
	5	56.0	59.0	59.2	60.4	62.8	3.0	0.2	1.2	2.4	3.2	1.4	3.6	4.4	3.8	6.8
	5.5	52.6	55.6	55.8	59.0	62.0	3.0	0.2	3.2	3.0	3.2	3.4	6.2	8.4	6.4	9.4
	6	55.6	57.8	59.0	83.8	69.6	2.2	1.2	4.6	6.0	3.4	5.8	10.6	8.0	11.8	14.0
	6.5	59.2	61.2	62.4	64.4	68.8	2.0	1.2	2.0	4.4	3.2	3.2	6.4	5.2	7.6	9.6
	7	62.6	63.8	65.2	66.6	68.4	1.2	1.4	1.4	1.8	2.6	2.8	3.2	4.0	4.6	5.8
	7.5	59.2	62.0	61.2	63.2	64.4	2.8	-0.8	2.0	1.2	2.0	1.2	3.2	4.0	2.4	5.2
	8	68.6	68.8	71.0	72.0	75.0	0.2	2.2	1.0	3.0	2.4	3.2	4.0	3.4	6.2	6.4
47066w	0	62.5	69.3	66.8	72.0	75.8	6.8	-2.5	5.3	3.8	4.3	2.8	9.0	9.5	6.5	13.3
	0.5	60.8	64.0	60.8	64.4	66.8	3.2	-3.2	3.6	2.4	0.0	0.4	6.0	3.8	2.8	6.0
	1	59.0	56.6	59.2	59.8	64.2	-2.4	2.6	0.6	4.4	0.2	3.2	5.0	0.8	7.6	5.2
	1.5	54.8	56.0	58.4	59.0	63.8	1.2	2.4	0.6	4.8	3.6	3.0	5.4	4.2	7.8	9.0
	2	66.2	66.8	70.0	71.0	73.6	0.6	3.2	1.0	2.6	3.8	4.2	3.6	4.8	6.8	7.4
	2.5	62.4	64.2	65.6	65.8	73.0	1.8	1.4	0.2	7.2	3.2	1.6	7.4	3.4	8.8	10.6
	3	63.5	67.8	68.0	67.8	68.5	4.3	0.3	-0.3	0.8	4.5	0.0	0.5	4.3	0.8	5.0
	3.5	66.0	66.6	72.4	71.2	71.2	0.6	5.8	-1.2	0.0	6.4	4.6	-1.2	5.2	4.6	5.2
	4	63.2	65.4	69.0	71.4	70.8	2.2	3.6	2.4	-0.6	5.8	6.0	1.8	8.2	5.4	7.6
	4.5	61.8	63.6	84.6	66.2	67.8	1.8	1.0	1.6	1.6	2.8	2.6	3.2	4.4	4.2	6.0
	5	57.2	60.2	83.8	62.0	66.6	3.0	3.6	-1.8	4.6	6.6	1.8	2.8	4.8	6.4	9.4
	5.5	55.8	58.0	59.6	59.6	61.4	2.2	1.6	0.0	1.8	3.8	1.6	1.8	3.8	3.4	5.6
	6	60.8	64.8	66.4	87.0	68.2	4.0	1.6	0.6	1.2	5.6	2.2	1.8	6.2	3.4	7.4
	6.5	61.2	64.8	68.2	66.2	67.4	3.6	3.4	-2.0	1.2	7.0	1.4	-0.8	5.0	2.6	6.2
	7	60.8	63.4	65.0	65.2	67.8	2.6	1.6	0.2	2.6	4.2	1.8	2.8	4.4	4.4	7.0
	7.5	59.6	63.0	68.4	67.2	68.4	3.4	5.4	-1.2	1.2	8.8	4.2	0.0	7.6	5.4	8.8
	8	63.5	65.2	66.8	67.2	69.2	1.7	1.6	0.4	2.0	3.3	2.0	2.4	3.7	4.0	5.7
81076n	0	83.0	88.0	88.6	85.8	89.4	5.0	0.6	-2.8	3.6	5.6	-2.2	0.8	2.8	1.4	6.4
	0.5	77.6	80.6	78.8	78.2	77.4	3.0	-1.8	-0.6	-0.8	1.2	-2.4	-1.4	0.6	-3.2	-0.2
	1	79.2	82.0	85.0	82.8	83.8	2.8	3.0	-2.2	1.0	5.8	0.8	-1.2	3.6	1.8	4.6
	1.5	79.4	81.8	82.8	82.0	83.6	2.4	1.0	-0.8	1.6	3.4	0.2	0.8	2.6	1.8	4.2
	2	77.4	78.2	81.2	79.6	80.4	0.8	3.0	-1.6	0.8	3.8	1.4	-0.8	2.2	2.2	3.0
	2.5	78.2	80.0	81.4	76.4	80.6	1.8	1.4	-5.0	4.2	3.2	-3.6	-0.8	-1.8	0.6	2.4
	3	74.8	80.0	79.4	77.4	79.0	5.2	-0.6	-2.0	1.6	4.8	-2.6	-0.4	2.6	-1.0	4.2
	3.5	73.0	80.4	77.4	80.6	o1.6	7.4	-3.0	3.2	1.0	4.4	0.2	4.2	7.6	1.2	8.6
	4	72.2	77.0	77.0	77.2	74.2	4.8	0.0	0.2	-3.0	4.8	0.2	-2.8	5.0	-2.8	2.0
	4.5	85.2	85.2	83.2	85.8	81.6	0.0	-2.0	2.6	-4.2	-2.0	0.6	-1.6	0.6	-3.6	-3.6
	5	92.2	89.0	85.6	90.2	91.2	-3.2	-3.4	4.6	1.0	-6.6	1.2	5.6	-2.0	2.2	-1.0
	5.5	76.8	83.2	79.6	82.0	80.4	8.4	-3.6	2.4	-1.6	2.8	-1.2	0.8	5.2	-2.8	3.6
	6	73.4	79.4	80.0	79.6	80.0	6.0	0.6	-0.4	0.4	6.6	0.2	0.0	6.2	0.6	6.6
81076s	0	83.2	78.8	83.8	78.6	82.6	-4.4	5.0	-5.2	4.0	0.6	-0.2	-1.2	-4.6	3.8	-0.6
	0.5	59.8	64.8	71.4	67.6	71.0	5.0	6.6	-3.8	3.4	11.6	2.8	-0.4	7.8	6.2	11.2
	1	68.0	70.4	71.8	69.2	72.8	2.4	1.4	-2.6	3.6	3.8	-1.2	1.0	1.2	2.4	4.8
	1.5	64.0	72.4	73.6	68.2	75.0	8.4	1.2	-5.4	8.8	9.8	-4.2	1.4	4.2	2.6	11.0

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	96	93-92	94-93	95-94	96-95	94-92	95-93	96-94	95-92	96-93	96-92
81076s	2	69.2	81.2	80.2	75.4	79.4	12.0	-1.0	-4.8	4.0	11.0	-5.8	-0.8	6.2	-1.8	10.2
	2.5	72.4	76.6	78.2	76.4	78.8	4.2	1.6	-1.8	2.2	5.8	-0.2	0.4	4.0	2.0	6.2
	3	73.0	73.0	73.2	68.6	71.6	0.0	0.2	-4.6	3.0	0.2	-4.4	-1.6	-4.4	-1.4	-1.4
	3.5	68.6	75.4	73.4	72.0	73.0	6.8	-2.0	-1.4	1.0	4.8	-3.4	-0.4	3.4	-2.4	4.4
	4	66.2	71.2	76.4	70.8	74.0	5.0	5.2	-5.8	3.2	10.2	-0.4	-2.4	4.6	2.8	7.8
	4.5	72.2	72.0	75.8	77.2	79.6	-0.2	3.8	1.4	2.4	3.8	5.2	3.8	5.0	7.6	7.4
	5	74.4	75.0	81.2	77.0	88.0	0.6	6.2	-4.2	11.0	6.8	2.0	6.8	2.6	13.0	13.6
	5.5	78.8	76.2	75.4	75.4	80.6	-0.6	-0.8	0.0	5.2	-1.4	-0.8	5.2	-1.4	4.4	3.8
	6	73.6	77.0	80.8	78.8	81.2	3.4	3.8	-2.0	2.4	7.2	1.8	0.4	5.2	4.2	7.6
19043n	5	50.6	N.A.	50.2	53.2	55.0	N.A.	N.A.	3.0	1.8	-0.4	N.A.	4.8	2.6	N.A.	4.4
	5.5	50.8	N.A.	54.6	58.4	57.0	N.A.	N.A.	3.8	-1.4	3.8	N.A.	2.4	7.6	N.A.	6.2
	6	56.2	N.A.	48.0	54.0	60.2	N.A.	N.A.	6.0	6.2	-8.2	N.A.	12.2	-2.2	N.A.	4.0
	6.5	47.4	N.A.	48.0	56.8	52.0	N.A.	N.A.	8.8	-4.8	0.8	N.A.	4.0	9.4	N.A.	4.6
	7	47.0	N.A.	48.2	54.2	58.8	N.A.	N.A.	8.0	4.6	-0.8	N.A.	12.6	7.2	N.A.	11.8
	7.5	50.2	N.A.	45.4	52.0	56.6	N.A.	N.A.	6.6	4.6	-4.8	N.A.	11.2	1.8	N.A.	6.4
19043s	5	49.6	54.6	53.4	55.4	55.4	5.0	-1.2	2.0	0.0	3.8	0.8	2.0	5.8	0.8	5.8
	5.5	51.8	50.4	50.8	57.8	53.6	-1.4	0.4	6.8	-4.0	-1.0	7.2	2.8	5.8	3.2	1.8
	6	45.4	47.6	46.2	50.0	50.0	2.2	-1.4	3.8	0.0	0.8	2.4	3.8	4.6	2.4	4.6
	6.5	49.0	49.6	50.0	58.8	51.7	0.6	0.4	8.8	-7.1	1.0	9.2	1.7	9.8	2.1	2.7
	7	53.0	55.0	55.3	55.0	54.5	2.0	0.3	-0.3	-0.5	2.3	0.0	-0.8	2.0	-0.5	1.5
	7.5	48.8	51.2	51.6	52.6	54.6	2.4	0.4	1.0	2.0	2.8	1.4	3.0	3.8	3.4	5.8
21022e	6.5	66.4	67.0	69.2	69.6	73.2	0.6	2.2	0.4	3.6	2.8	2.6	4.0	3.2	6.2	8.8
	7	57.2	55.8	59.8	57.8	61.8	-1.4	4.0	-2.0	4.0	2.6	2.0	2.0	0.6	6.0	4.6
	7.5	62.8	55.0	59.8	82.0	58.4	-7.8	4.6	2.4	-5.6	-3.2	7.0	-3.2	-0.8	1.4	-6.4
	8	75.4	67.2	77.2	75.4	73.2	-8.2	10.0	-1.8	-2.2	1.8	8.2	-4.0	0.0	6.0	-2.2
21022w	6.5	62.0	63.2	66.4	64.2	63.6	1.2	3.2	-2.2	-0.6	4.4	1.0	-2.8	2.2	0.4	1.6
	7	58.0	55.6	60.0	58.8	61.2	-2.4	4.4	-1.2	2.4	2.0	3.2	1.2	0.8	5.6	3.2
	7.5	52.2	52.0	53.8	55.6	53.2	-0.2	1.8	1.8	-2.4	1.8	3.8	-0.6	3.4	1.2	1.0
	8	78.4	71.0	70.8	67.2	75.0	-7.4	-0.2	-3.6	7.8	-7.6	-3.8	4.2	-11.2	4.0	-3.4
25132n2	7	49.2	44.0	50.8	49.4	59.4	-5.2	6.8	-1.4	10.0	1.6	5.4	8.6	0.2	15.4	10.2
	7.5	47.6	47.4	48.4	50.6	55.6	-0.2	1.0	2.2	5.0	0.8	3.2	7.2	3.0	8.2	8.0
	8	56.3	55.0	56.5	45.0	53.0	-1.3	1.5	-11.5	8.0	0.3	-10.0	-3.5	-11.3	-2.0	-3.3
	8.5	64.0	68.0	67.3	61.5	61.0	4.0	-0.7	-5.8	-0.5	3.3	-6.5	-6.3	-2.5	-7.0	-3.0
	9	49.8	55.3	53.5	50.8	55.5	5.5	-1.8	-2.8	4.8	3.8	-4.5	2.0	1.0	0.3	5.8
	9.5	51.7	55.0	51.7	54.7	56.3	3.3	-3.3	3.0	1.7	0.0	-0.3	4.7	3.0	1.3	4.7
	10	58.8	53.5	55.8	49.0	54.5	-5.3	2.3	-6.8	5.5	-3.0	-4.5	-1.3	-9.8	1.0	-4.3
	10.5	53.0	52.3	56.5	52.8	59.3	-0.8	4.3	-3.8	6.6	3.5	0.5	2.8	-0.3	7.1	6.3
	11	51.8	50.6	52.0	53.2	57.6	-1.2	1.4	1.2	4.4	0.2	2.6	5.6	1.4	7.0	5.8
	11.5	59.6	56.4	59.4	59.4	62.4	-3.2	3.0	0.0	3.0	-0.2	3.0	3.0	-0.2	6.0	2.8
	12	59.6	59.2	60.6	62.6	69.6	-0.4	1.4	2.0	7.0	1.0	3.4	9.0	3.0	10.4	10.0
	12.5	53.6	51.2	51.0	55.6	57.0	-2.4	-0.2	4.6	1.4	-2.8	4.4	6.0	2.0	5.8	3.4
33172n	0	57.0	55.8	55.4	57.0	57.4	-1.2	-0.4	1.6	0.4	-1.8	1.2	2.0	0.0	1.6	0.4
	0.5	56.0	56.6	58.6	59.6	58.6	0.6	0.0	3.0	-1.0	0.6	3.0	2.0	3.6	2.0	2.6
	1	57.2	57.4	57.6	59.6	59.8	0.2	0.2	2.0	0.2	0.4	2.2	2.2	2.4	2.4	2.6
	1.5	53.8	54.6	56.2	57.4	61.8	0.8	1.8	1.2	4.4	2.4	2.8	5.8	3.6	7.2	8.0

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	96	93-92	94-93	95-94	96-95	94-92	95-93	96-94	95-92	96-93	96-92
33172s	0	59.8	58.0	58.4	58.4	61.0	-1.6	0.4	0.0	2.6	-1.4	0.4	2.8	-1.4	3.0	1.2
	0.5	52.2	53.4	54.6	57.0	56.8	1.2	1.2	2.4	-0.2	2.4	3.6	2.2	4.8	3.4	4.6
	1	55.6	56.0	55.4	62.2	58.6	0.4	-0.6	6.8	-3.6	-0.2	6.2	3.2	6.6	2.6	3.0
	1.5	61.0	62.0	60.6	61.6	63.0	1.0	-1.4	1.0	1.4	-0.4	-0.4	2.4	0.6	1.0	2.0
39022w	4.5	44.8	48.0	50.8	50.6	54.2	3.2	2.6	0.0	3.8	5.6	2.6	3.8	5.6	6.2	9.4
	5	46.4	51.4	50.8	50.2	53.8	5.0	-0.6	-0.6	3.4	4.4	-1.2	2.8	3.6	2.2	7.2
	5.5	49.4	49.6	55.2	49.6	54.8	0.2	5.6	-5.6	5.2	5.8	0.0	-0.4	0.2	5.2	5.4
	6	50.8	50.6	52.0	51.0	53.2	-0.2	1.4	-1.0	2.2	1.2	0.4	1.2	0.2	2.6	2.4
	6.5	48.2	52.2	52.0	51.6	53.4	4.0	-0.2	-0.4	1.8	3.6	-0.6	1.4	3.4	1.2	5.2
	7	53.2	54.6	54.6	59.4	59.6	1.4	0.0	4.8	0.2	1.4	4.6	5.0	6.2	5.0	6.4
	7.5	57.0	62.0	65.8	84.4	72.4	5.0	3.8	-1.4	8.0	8.8	2.4	6.6	7.4	10.4	15.4
	8	53.2	56.4	59.0	61.0	63.0	3.2	2.6	2.0	2.0	5.6	4.6	4.0	7.8	6.6	9.8
	8.5	58.6	55.6	59.2	60.4	65.0	-1.0	3.8	1.2	4.6	2.6	4.6	5.8	3.8	9.4	8.4
	9	49.0	53.2	57.0	61.8	63.2	4.2	3.6	4.8	1.4	6.0	6.6	6.2	12.8	10.0	14.2
	9.5	45.6	52.6	56.4	61.6	67.4	7.0	5.8	3.2	5.6	12.8	9.0	9.0	16.0	14.8	21.8
	10	52.0	56.0	59.4	62.6	64.2	4.0	3.4	3.2	1.6	7.4	6.6	4.8	10.6	8.2	12.2
	10.5	51.0	59.2	66.6	68.4	74.4	8.2	7.4	-0.2	6.0	15.6	7.2	7.8	15.4	15.2	23.4
	11	43.8	50.8	48.0	48.5	52.5	7.0	-2.8	0.5	4.0	4.3	-2.3	4.5	4.8	1.8	8.8
49025n	8.5	62.6	55.8	51.2	52.2	51.0	-6.6	-4.6	1.0	-1.2	-11.4	-3.6	-0.2	-10.4	-4.6	-11.6
	9	48.0	49.4	46.2	50.2	47.4	1.4	-3.2	4.0	-2.6	-1.8	0.8	1.2	2.2	-2.0	-0.6
	9.5	46.6	46.6	44.8	48.5	45.8	0.0	-1.6	3.7	-2.7	-1.8	1.9	1.0	1.9	-0.8	-0.8
	10	58.2	55.6	53.6	56.4	55.6	-0.6	-2.0	2.8	-0.8	-2.6	0.8	2.0	0.2	0.0	-0.6
	10.5	64.6	65.6	61.6	61.8	64.4	1.0	-3.8	0.0	2.6	-2.8	-3.8	2.6	-2.8	-1.2	-0.2
	11	54.8	58.8	57.0	56.8	60.2	4.0	-1.8	-0.2	3.4	2.2	-2.0	3.2	2.0	1.4	5.4
	11.5	42.0	41.8	43.6	46.6	50.2	-0.2	1.8	3.0	3.6	1.6	4.8	6.6	4.6	8.4	8.2
	12	42.0	44.5	N.A.	45.0	49.3	2.5	N.A.	N.A.	4.3	N.A.	0.5	N.A.	3.0	4.8	7.3
	12.5	50.3	43.8	45.3	51.3	53.8	-6.5	1.5	6.0	2.5	-5.0	7.5	8.5	1.0	10.0	3.5
	13	39.8	37.8	39.4	41.4	41.8	-1.8	1.6	2.0	0.4	-0.2	3.6	2.4	1.8	4.0	2.2
	13.5	41.0	40.0	40.0	42.6	44.2	-1.0	0.0	2.6	1.6	-1.0	2.6	4.2	1.6	4.2	3.2
	14	42.0	40.4	43.0	45.2	43.2	-1.6	2.6	2.2	-2.0	1.0	4.8	0.2	3.2	2.8	1.2
	14.5	47.2	47.2	47.8	47.8	49.4	0.0	0.4	0.2	1.6	0.4	0.6	1.8	0.6	2.2	2.2
	15	49.4	47.0	51.8	48.4	50.8	-2.4	4.8	-3.4	2.4	2.4	1.4	-1.0	-1.0	3.8	1.4
	15.5	40.8	41.8	42.8	45.8	47.4	1.0	1.0	3.0	1.6	2.0	4.0	4.6	5.0	5.6	6.6
	16	35.6	37.2	34.8	37.2	37.6	1.4	-2.4	2.4	0.4	-1.0	0.0	2.6	1.4	0.4	1.8
	16.5	39.0	41.4	41.2	43.6	41.8	2.4	-0.2	2.4	-1.8	2.2	2.2	0.6	4.8	0.4	2.8
	17	42.8	43.2	43.0	47.0	44.6	0.4	-0.2	4.0	-2.4	0.2	3.8	1.6	4.2	1.4	1.8
	17.5	37.8	38.2	37.0	40.4	40.0	0.4	-1.2	3.4	-0.4	-0.8	2.2	3.0	2.6	1.8	2.2
	18	42.0	44.2	44.0	41.6	40.2	2.2	-0.2	-2.4	-1.4	2.0	-2.6	-3.8	-0.4	-4.0	-1.8
	18.5	34.8	37.8	38.2	39.8	37.6	2.8	0.6	1.6	-2.2	3.4	2.2	-0.8	5.0	0.0	2.8
	19	42.4	40.6	43.4	46.6	44.0	-1.8	2.6	3.2	-2.6	1.0	6.0	0.8	4.2	3.4	1.6
	19.5	50.0	52.0	53.2	53.6	52.0	2.0	1.2	0.6	-1.6	3.2	1.8	-1.2	3.8	0.0	2.0
	20	51.8	58.4	52.2	55.2	49.6	6.6	-6.2	3.0	-5.6	0.4	-3.2	-2.6	3.4	-8.8	-2.2
	20.5	50.2	52.0	59.0	59.0	49.8	1.8	7.0	0.0	-9.2	8.8	7.0	-9.2	8.8	-2.2	-0.4
	21	45.5	45.5	49.0	49.0	40.3	0.0	3.5	0.0	-8.7	3.5	3.5	-8.7	3.5	-5.2	-5.2
	21.5	48.4	47.6	50.6	49.0	48.8	-0.8	3.0	-1.6	-0.2	2.2	1.4	-1.8	0.6	1.2	0.4

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	96	93-92	94-93	95-94	96-95	94-92	95-93	96-94	95-92	96-93	96-92
49025n	22	36.6	39.2	42.6	40.2	36.4	2.6	3.4	-2.4	-3.8	6.0	1.0	-6.2	3.6	-2.8	-0.2
	22.5	37.4	40.6	45.4	45.6	40.2	3.2	4.8	0.2	-5.4	8.0	5.0	-5.2	8.2	-0.4	2.8
	23	43.6	44.2	49.6	49.8	45.2	0.4	5.4	0.2	-4.6	5.8	5.6	-4.4	6.0	1.0	1.4
	23.5	54.8	48.0	52.2	55.6	49.4	-6.8	4.2	3.4	-6.2	-2.6	7.6	-2.8	0.6	1.4	-5.4
	24	54.0	48.4	60.8	51.8	46.8	-5.6	12.4	-9.0	-5.0	6.8	3.4	-14.0	-2.2	-1.6	-7.2
	24.5	49.8	46.8	54.2	50.6	45.8	-3.0	7.4	-3.6	-4.8	4.4	3.6	-8.4	0.8	-1.0	-4.0
49025s	8.5	47.6	48.2	46.6	45.4	48.0	0.6	-1.6	-1.2	2.6	-1.0	-2.8	1.4	-2.2	-0.2	0.4
	9	48.8	45.8	47.4	49.6	50.0	-3.0	1.6	2.2	0.4	-1.4	3.8	2.6	0.8	4.2	1.2
	9.5	46.6	43.4	43.6	48.0	48.2	-3.2	0.2	4.4	0.2	-3.0	4.6	4.6	1.4	4.6	1.6
	10	48.8	55.4	49.4	48.8	50.4	6.6	-6.0	-0.6	1.6	0.6	-6.6	1.0	0.0	-5.0	1.6
	10.5	50.4	52.8	49.4	48.2	47.4	2.4	-3.4	-1.2	-0.8	-1.0	-4.6	-2.0	-2.2	-5.4	-3.0
	11	60.6	59.8	61.0	61.2	62.8	-0.8	1.2	0.2	1.6	0.4	1.4	1.8	0.6	3.0	2.2
	11.5	52.8	51.2	52.2	53.0	53.4	-1.6	1.0	0.8	0.4	-0.6	1.8	1.2	0.2	2.2	0.6
	12	51.0	52.8	53.8	59.0	59.2	1.8	1.0	5.3	0.2	2.8	6.3	5.5	8.0	6.5	8.2
	12.5	51.0	49.5	50.3	51.3	50.0	-1.5	0.8	1.0	-1.3	-0.8	1.8	-0.3	0.3	0.5	-1.0
	13	50.2	48.4	50.8	49.8	51.5	-1.8	2.4	-1.0	1.7	0.6	1.4	0.7	-0.4	3.1	1.3
	13.5	42.0	41.8	42.2	44.2	47.0	-0.4	0.8	2.0	2.8	0.2	2.6	4.8	2.2	5.4	5.0
	14	43.2	42.8	44.4	44.6	46.4	-0.4	1.6	0.2	1.8	1.2	1.8	2.0	1.4	3.6	3.2
	14.5	52.2	50.0	51.6	51.6	53.2	-2.2	1.6	0.0	1.6	-0.6	1.6	1.6	-0.6	3.2	1.0
	15	50.6	50.2	52.0	55.0	56.8	-0.4	1.8	3.0	1.8	1.4	4.8	4.8	4.4	6.6	6.2
	15.5	44.2	45.2	48.4	47.8	50.0	1.0	3.2	-0.6	2.2	4.2	2.6	1.6	3.6	4.6	5.6
	16	36.2	36.0	36.8	39.0	41.0	-0.2	0.8	2.2	2.0	0.6	3.0	4.2	2.6	5.0	4.6
	16.5	36.4	34.4	39.6	43.4	40.4	-2.0	5.2	3.8	-3.0	3.2	9.0	0.8	7.0	6.0	4.0
	17	44.2	45.0	45.4	52.8	48.6	0.8	0.4	7.4	-4.2	1.2	7.8	3.2	8.6	3.6	4.4
	17.5	41.2	42.6	44.2	50.8	45.4	1.4	1.6	6.6	-5.4	3.0	8.2	1.2	9.6	2.8	4.2
	18	37.0	38.0	39.0	42.8	42.2	1.0	1.0	3.6	-0.4	2.0	4.6	3.2	5.6	4.2	5.2
	18.5	37.0	41.4	43.6	41.8	44.0	4.4	2.2	-1.8	2.2	6.6	0.4	0.4	4.8	2.6	7.0
	19	39.4	43.0	45.8	49.4	53.2	3.6	2.8	3.6	3.8	6.4	6.4	7.4	10.0	10.2	13.8
	19.5	48.6	52.6	54.2	51.0	57.0	4.0	1.6	-3.2	6.0	5.6	-1.6	2.8	2.4	4.4	8.4
	20	48.0	52.2	52.8	57.4	58.0	4.2	0.6	4.6	0.6	4.8	5.2	5.2	9.4	5.8	10.0
	20.5	44.0	46.4	51.2	52.6	54.0	2.4	4.8	1.4	1.4	7.2	6.2	2.8	8.6	7.6	10.0
	21	49.3	58.3	53.3	52.3	52.0	9.0	-5.0	-0.9	-0.3	4.0	-5.9	-1.3	3.1	-6.3	2.8
	21.5	36.2	41.6	39.4	44.8	45.0	5.4	-2.2	5.4	0.2	3.2	3.2	5.6	6.6	3.4	8.8
	22	33.0	37.2	39.0	44.8	41.4	4.2	1.8	5.8	-3.4	6.0	7.6	2.4	11.8	4.2	8.4
	22.5	35.2	37.4	40.2	49.6	43.6	2.2	2.8	9.4	-6.0	5.0	12.2	3.4	14.4	6.2	8.4
	23	38.6	39.2	40.4	49.0	42.4	0.6	1.2	8.6	-6.6	1.8	9.8	2.0	10.4	3.2	3.8
	23.5	46.0	45.8	45.4	50.2	47.6	-0.2	-0.4	4.8	-2.6	-0.6	4.4	2.2	4.2	1.8	1.6
	24	50.4	51.2	53.6	56.8	55.6	0.8	2.4	3.2	-1.2	3.2	5.6	2.0	6.4	4.4	5.2
	24.5	47.6	50.2	53.2	54.6	54.0	2.6	3.0	1.4	-0.6	5.6	4.4	0.8	7.0	3.8	6.4
63031n	4.5	61.4	63.0	65.0	64.8	62.8	1.6	2.0	-0.3	-2.0	3.6	1.6	-2.2	3.4	-0.2	1.4
	5	78.6	78.2	79.2	78.2	76.3	-0.4	1.0	-1.0	-2.0	0.6	0.0	-3.0	-0.4	-2.0	-2.3
	5.5	66.4	73.4	70.8	68.0	73.4	7.0	-2.6	-2.8	5.4	4.4	-5.4	2.6	1.6	0.0	7.0
	6	67.0	64.0	69.6	70.8	73.8	-3.0	5.6	1.2	3.0	2.6	6.8	4.2	3.8	9.8	6.8
	7.5	73.6	72.6	77.0	78.2	63.6	-1.0	4.4	1.2	5.4	3.4	5.6	6.6	4.6	11.0	10.0
	8	70.4	70.4	73.2	75.0	76.4	0.0	2.8	1.8	1.4	2.8	4.6	3.2	4.6	6.0	6.0

RQI Increase Rate for Rigid Pavements (Continued)

CS	M.P.	RQI					1 year Increase Rate				2 Year Increase Rate			3 Year Increase Rate		4Year Increase Rate
		92	93	94	95	98	93-92	94-93	95-94	96-95	94-92	95-93	98-94	95-92	96-93	96-92
63031n	9	61.2	62.2	62.4	63.4	61.0	1.0	0.2	1.0	-2.4	1.2	1.2	-1.4	2.2	-1.2	-0.2
	10	70.0	75.4	77.2	76.0	77.6	5.4	1.8	0.8	-0.4	7.2	2.8	0.4	8.0	2.2	7.8
	10.5	72.0	73.6	80.0	77.8	76.5	1.6	6.4	-2.2	-1.3	8.0	4.2	-3.5	5.8	2.9	4.5
63111n	0	59.6	59.2	60.2	61.4	60.6	-0.4	1.0	1.2	-0.8	0.6	2.2	0.4	1.8	1.4	1.0
	0.5	71.0	73.4	73.0	77.2	72.4	2.4	-0.4	4.2	-4.8	2.0	3.8	-0.6	6.2	-1.0	1.4
	1	62.3	70.0	72.6	72.0	70.3	7.8	2.8	-0.8	-1.8	10.6	2.0	-2.6	9.8	0.3	8.0
64016n	0	N.A.	58.0	56.0	58.0	61.4	N.A.	-2.0	2.0	3.4	N.A.	0.0	5.4	N.A.	3.4	N.A.
	0.5	N.A.	47.6	47.0	50.0	51.8	N.A.	-0.6	3.0	1.8	N.A.	2.4	4.8	N.A.	4.2	N.A.
	1	N.A.	59.4	57.8	59.4	64.4	N.A.	-1.6	1.6	5.0	N.A.	0.0	6.6	N.A.	5.0	N.A.
	1.5	N.A.	63.8	67.0	66.7	64.3	N.A.	3.2	-0.3	-2.4	N.A.	2.9	-2.8	N.A.	0.5	N.A.
	2	N.A.	73.6	72.2	73.4	74.8	N.A.	-1.4	1.2	1.4	N.A.	-0.2	2.6	N.A.	1.2	N.A.
70023e	4.5	N.A.	58.2	61.0	59.8	62.0	N.A.	2.8	-1.4	2.4	N.A.	1.4	1.0	N.A.	3.8	N.A.
	5	N.A.	61.4	61.4	64.8	64.4	N.A.	0.0	3.4	-0.4	N.A.	3.4	3.0	N.A.	3.0	N.A.
80024e'	0	56.6	62.6	62.2	67.6	70.2	8.0	-0.4	5.4	2.6	5.8	5.0	8.0	11.0	7.6	13.8
	0.5	63.8	68.2	71.0	72.4	78.2	4.4	2.8	1.4	3.8	7.2	4.2	5.2	8.6	8.0	12.4
	1	66.6	72.2	73.6	75.8	79.2	5.6	1.4	2.2	3.4	7.0	3.6	5.8	9.2	7.0	12.6
	1.5	65.6	70.8	72.4	74.2	79.2	5.2	1.6	1.8	5.0	6.8	3.4	6.8	8.6	8.4	13.6
	2	67.6	71.6	74.4	75.8	79.0	4.0	2.8	1.4	3.2	6.8	4.2	4.8	8.2	7.4	11.4
	2.5	61.6	70.6	72.4	72.8	77.4	9.0	1.8	0.4	4.6	10.8	2.2	5.0	11.2	6.8	15.8
	3	77.3	78.3	76.5	80.3	83.8	1.0	-1.8	3.8	3.5	-0.8	2.0	7.3	3.0	5.5	6.5
	3.5	72.0	78.6	78.6	82.2	85.8	6.6	0.0	3.6	3.8	8.8	3.6	7.2	10.2	7.2	13.8
	4	62.4	69.0	71.2	74.6	79.2	6.6	2.2	3.4	4.6	8.8	5.8	8.0	12.2	10.2	16.8
	4.5	66.8	72.6	75.4	77.4	79.6	5.8	2.8	2.0	2.2	8.6	4.8	4.2	10.6	7.0	12.8
82061w	9	75.0	N.A.	79.6	81.0	79.2	N.A.	N.A.	1.4	-1.8	4.8	N.A.	-0.4	6.0	N.A.	4.2
	9.5	74.2	N.A.	76.2	73.3	78.2	N.A.	N.A.	-3.0	5.0	2.0	N.A.	2.0	-1.0	N.A.	4.0
	10	66.4	N.A.	76.6	70.4	71.0	N.A.	N.A.	-6.2	0.6	10.2	N.A.	-5.6	4.0	N.A.	4.6
	10.5	63.5	N.A.	65.8	89.0	69.0	N.A.	N.A.	3.2	0.0	2.3	N.A.	3.2	5.5	N.A.	5.5

APPENDIX G
Correlating Roughness, DI and DL

Coefficient of Correlation between Various Axle Loads and the Reference Axle Load

Pavement Section	2-axle truck		3-axle truck			5-axle semi-trailer				
	Axle#1	Axle#2	Axle#1	Axle#2	Axle#3	Axle#1	Axle#2	Axle#3	Axle#4	Axle#5
11017-95 (MP. 2.6-2.7)	0.55	0.73	0.36	0.76	0.81	0.45	1.00	0.86	0.16	0.17
(MP. 3.6-3.7)	0.63	0.66	0.56	0.86	0.84	0.57	1.00	0.87	0.00	-0.15
(MP. 5.4-5.5)	0.39	0.81	0.16	0.72	0.59	0.37	1.00	0.76	0.28	0.29
09101-95 (MP. 1.6-1.7)	0.44	0.63	0.18	0.62	0.39	0.29	1.00	0.70	0.46	0.21
(MP. 2.3-2.4)	0.44	0.58	0.28	0.73	0.52	0.21	1.00	0.69	0.35	0.01
(MP. 3.1-3.2)	0.48	0.69	0.31	0.68	0.38	0.31	1.00	0.66	0.53	0.24
(MP. 5.0-5.1)	0.58	0.78	0.29	0.77	0.58	0.35	1.00	0.76	0.44	0.35
38101-95 (MP. 0.1-0.2)	0.57	0.77	0.35	0.78	0.65	0.49	1.00	0.84	0.25	0.15
(MP. 1.0-1.1)	0.44	0.60	0.19	0.73	0.52	0.30	1.00	0.68	0.26	-0.10
(MP. 4.4-4.5)	0.53	0.75	0.39	0.75	0.60	0.43	1.00	0.74	0.36	0.19
(MP. 5.3-5.4)	0.52	0.78	0.40	0.82	0.74	0.48	1.00	0.82	0.15	0.13
Average	0.51	0.71	0.32	0.75	0.60	0.39	1.00	0.76	0.30	0.13

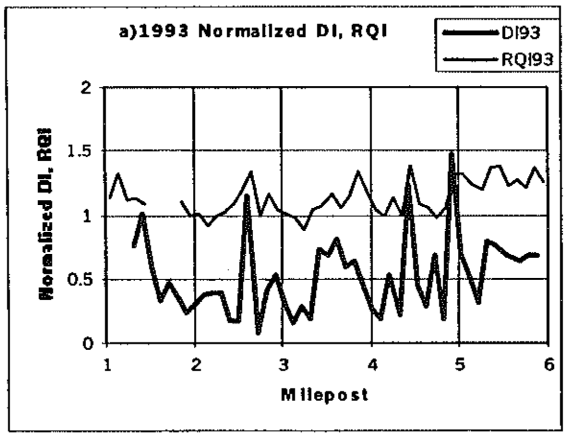
Coefficient of Correlation between Aggregate Axle Load of Different Trucks and the 2nd Axle Load of 5-Axle Semi-Trailer

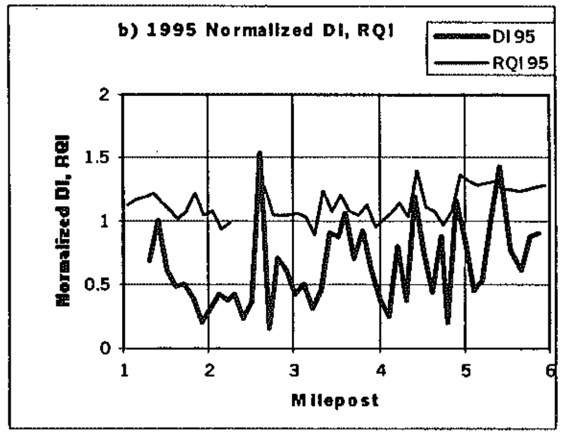
Pavement Section	2-Axle Truck	3-Axle Truck	5-Axle Trailer	Aggregate Load	Axle#2 of Semi-Trailer
11017-95 (MP. 2.6-2.7)	0.72	0.78	0.76	0.84	1.00
(MP. 3.6-3.7)	0.68	0.86	0.66	0.81	1.00
(MP. 5.4-5.5)	0.79	0.63	0.79	0.84	1.00
09101-95 (MP. 1.6-1.7)	0.60	0.51	0.74	0.74	1.00
(MP. 2.3-2.4)	0.56	0.64	0.66	0.71	1.00
(MP. 3.1-3.2)	0.65	0.57	0.75	0.76	1.00
(MP. 5.0-5.1)	0.76	0.69	0.83	0.87	1.00
38101-95 (MP. 0.1-0.2)	0.77	0.71	0.75	0.83	1.00
(MP. 1.0-1.1)	0.58	0.61	0.62	0.68	1.00
(MP. 4.4-4.5)	0.74	0.69	0.76	0.82	1.00
(MP. 5.3-5.4)	0.78	0.79	0.75	0.85	1.00
Average	0.69	0.68	0.73	0.80	1.00

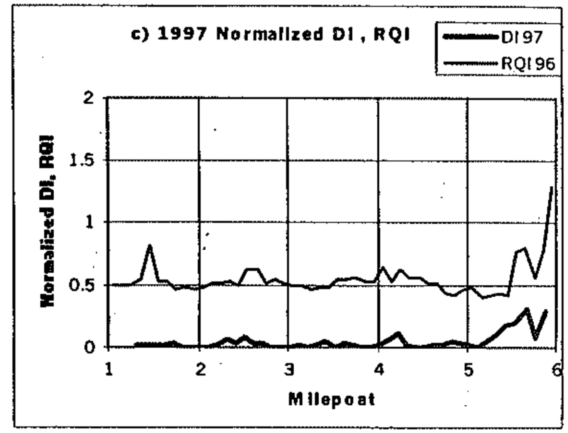
Coefficient of Correlation between Aggregate Axle Loads of Each Truck and Aggregate Axle Load from All Trucks

Pavement Section	2-Axle Truck	3-Axle Truck	5-Axle Trailer	All Trucks
11017-95 (MP. 2.6-2.7)	0.89	0.86	0.94	1.00
(MP. 3.6-3.7)	0.89	0.84	0.93	1.00
(MP. 5.4-5.5)	0.90	0.78	0.95	1.00
09101-95 (MP. 1.6-1.7)	0.88	0.72	0.96	1.00
(MP. 2.3-2.4)	0.90	0.73	0.96	1.00
(MP. 3.1-3.2)	0.92	0.73	0.97	1.00
(MP. 5.0-5.1)	0.91	0.74	0.97	1.00
38101-95 (MP. 0.1-0.2)	0.90	0.77	0.95	1.00
(MP. 1.0-1.1)	0.88	0.75	0.95	1.00
(MP. 4.4-4.5)	0.89	0.77	0.95	1.00
(MP. 5.3-5.4)	0.90	0.81	0.95	1.00
Average	0.90	0.77	0.95	1.00

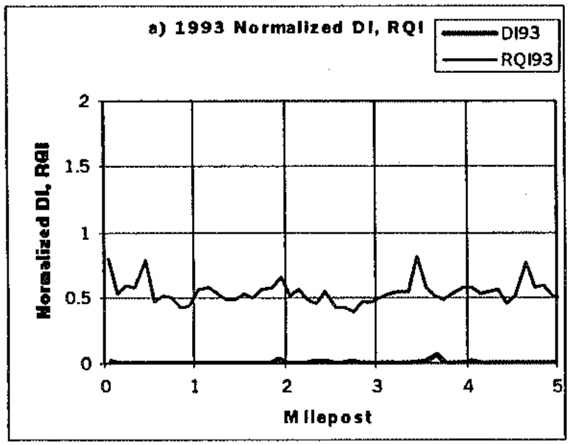
Distress and Roughness Profile along the Project Length for EB I-94 (CS 11017)

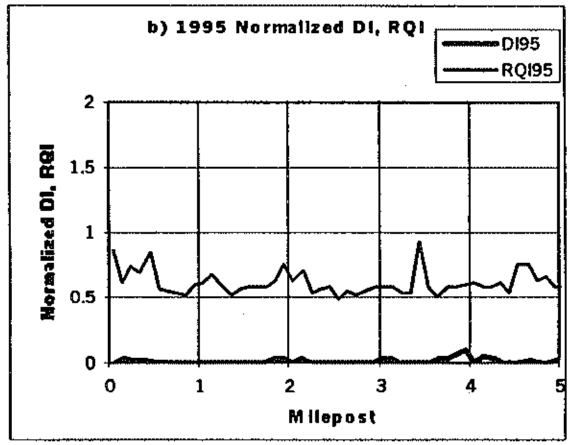


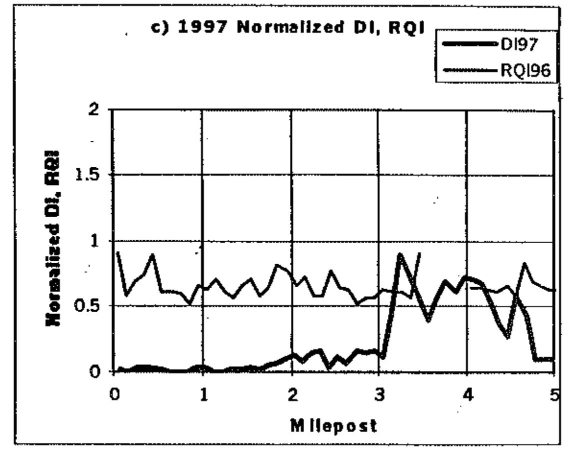




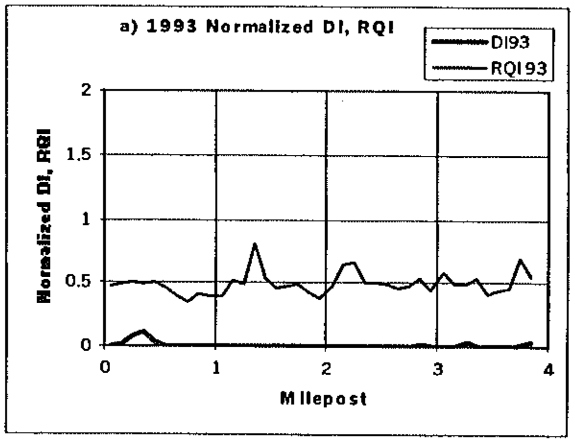
Distress and Roughness Profile along the Project Length for NB I-69 (CS 23063)

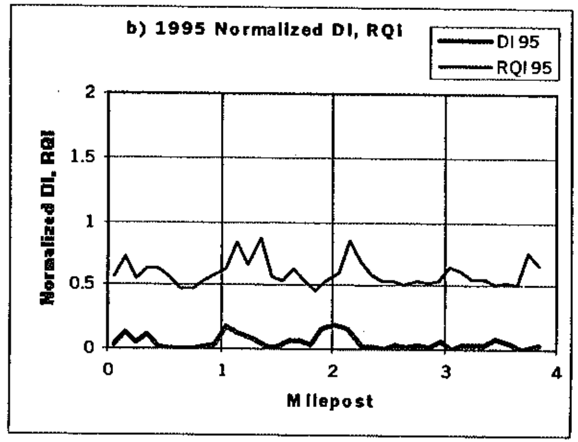


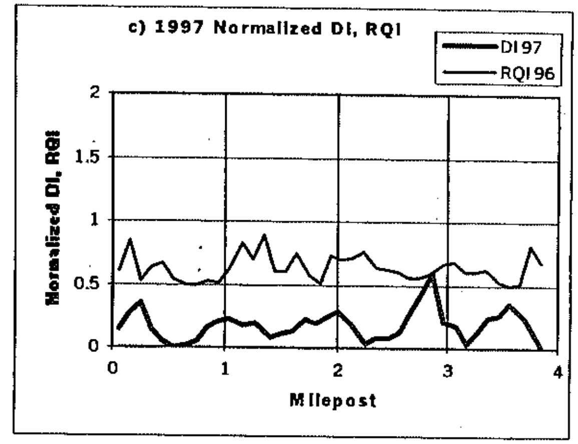




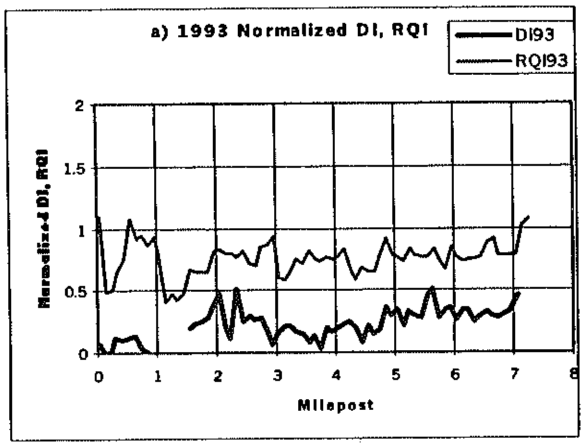
Distress and Roughness Profile along the Project Length for EB I-69 (CS 76024)

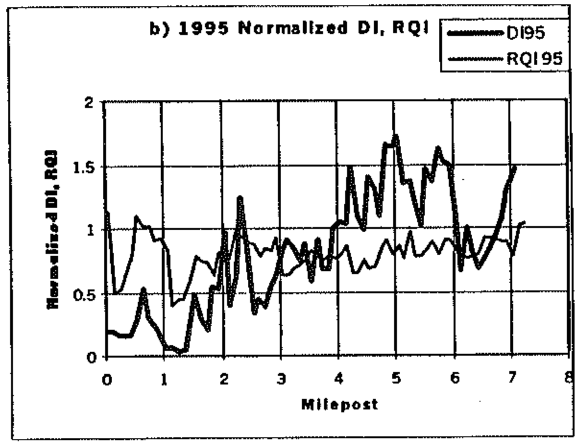


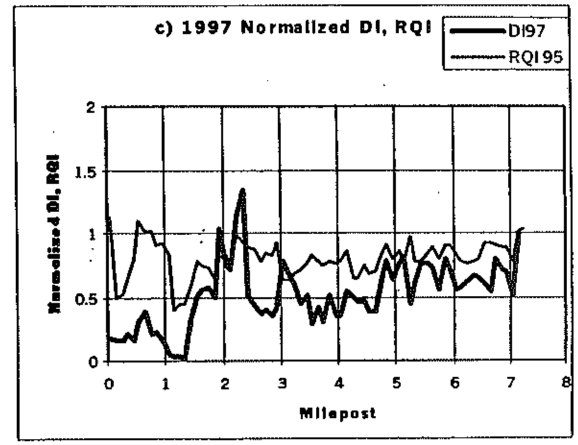




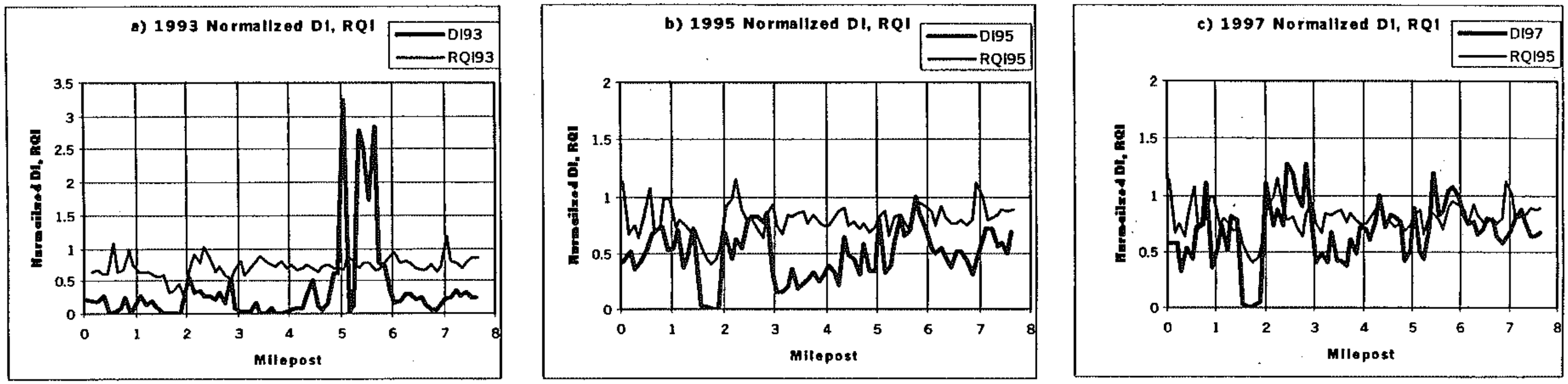
Distress and Roughness Profile along the Project Length for EB US-10 (CS 18024)



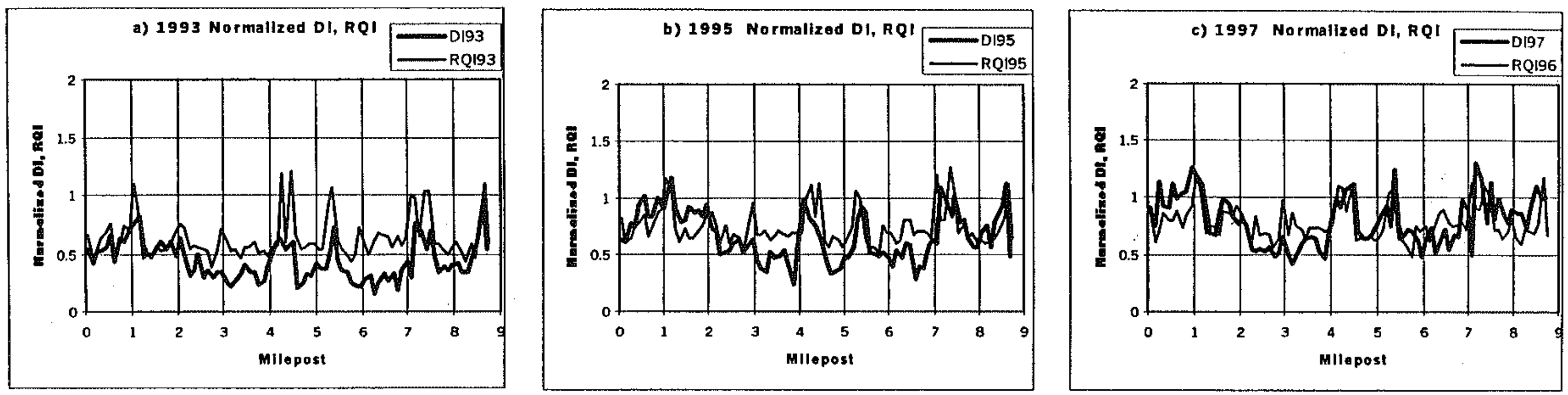




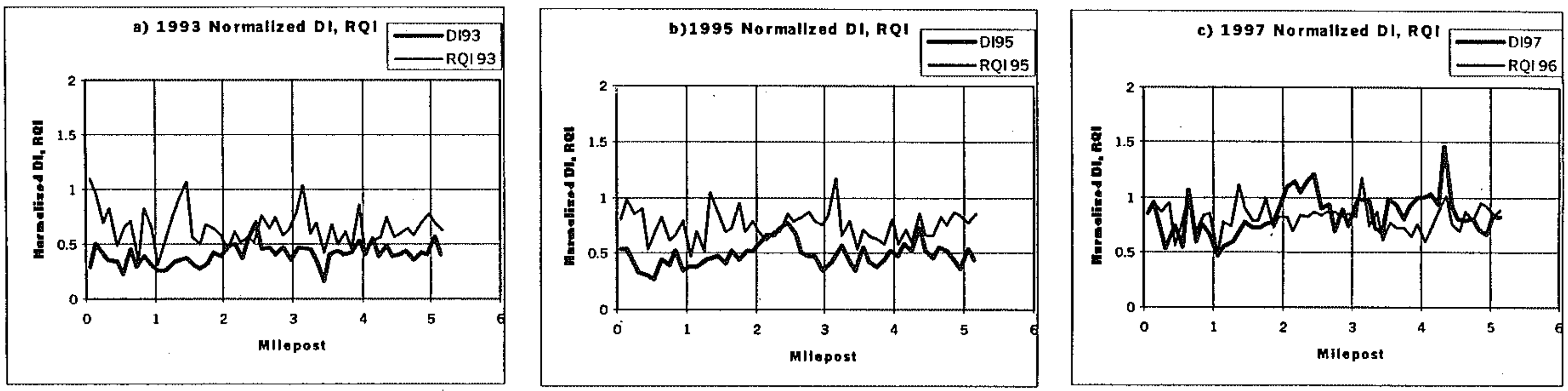
Distress and Roughness Profile along the Project Length for WB US-10 (CS 18024)



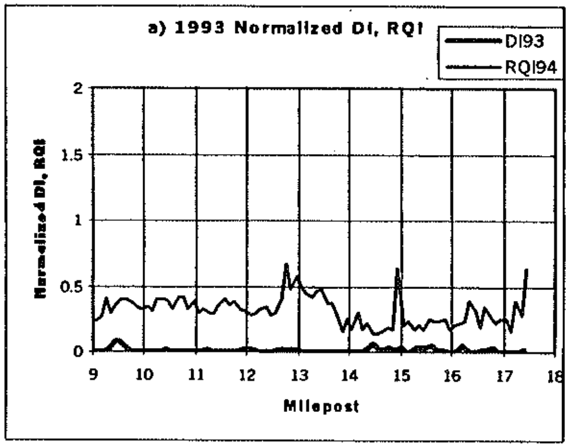
Distress and Roughness Profile along the Project Length for EB I-94 (CS 38101)

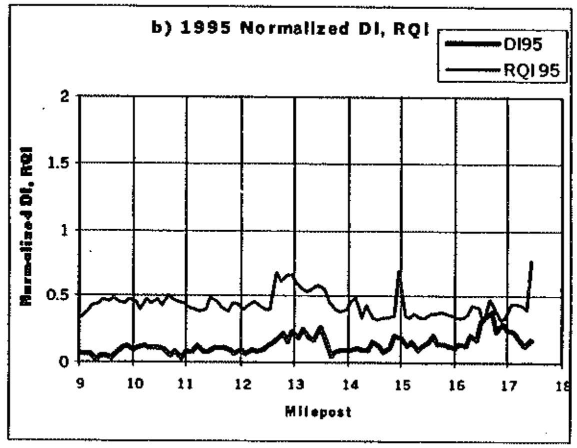


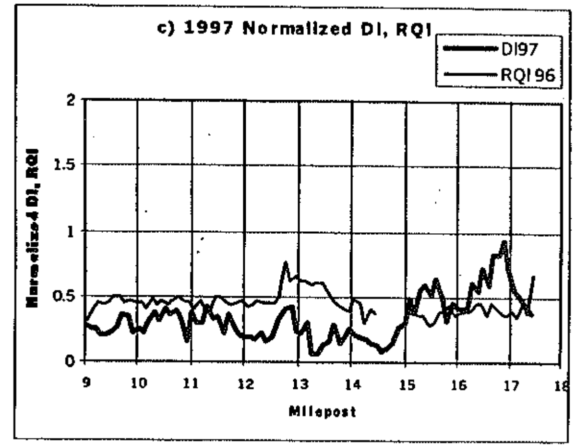
Distress and Roughness Profile along the Project Length for NB US-127 (CS 38131)



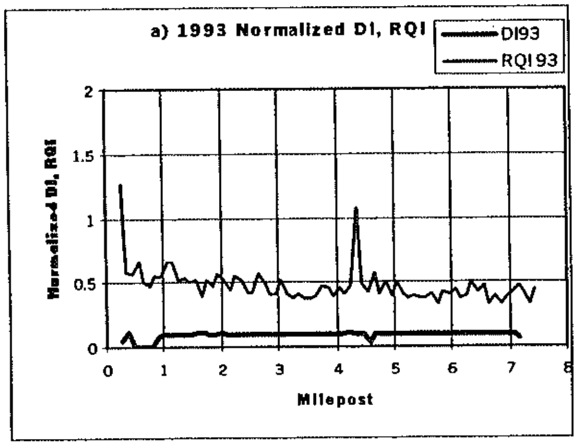
Distress and Roughness Profile along the Project Length for EB I-196 (CS 33084)

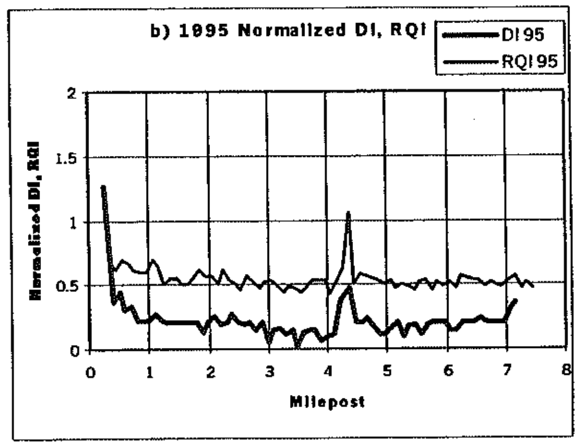


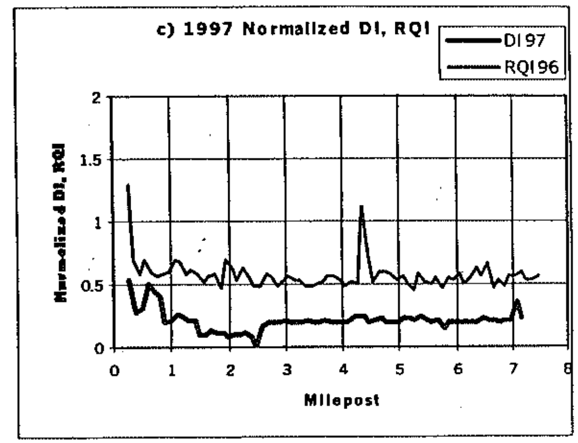




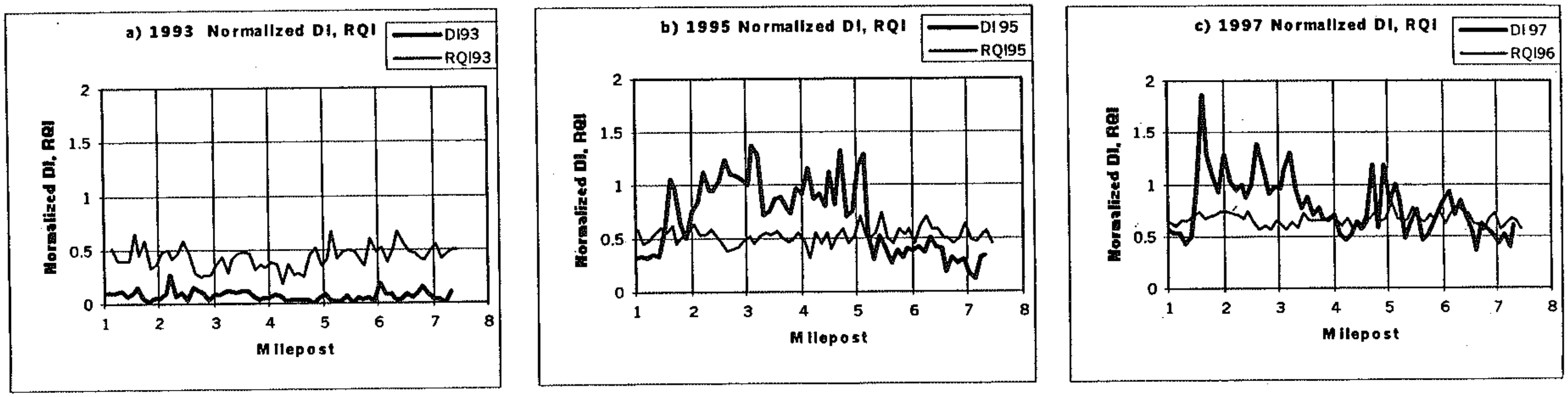
Distress and Roughness Profile along the Project Length for NB US-23 (CS 47014)

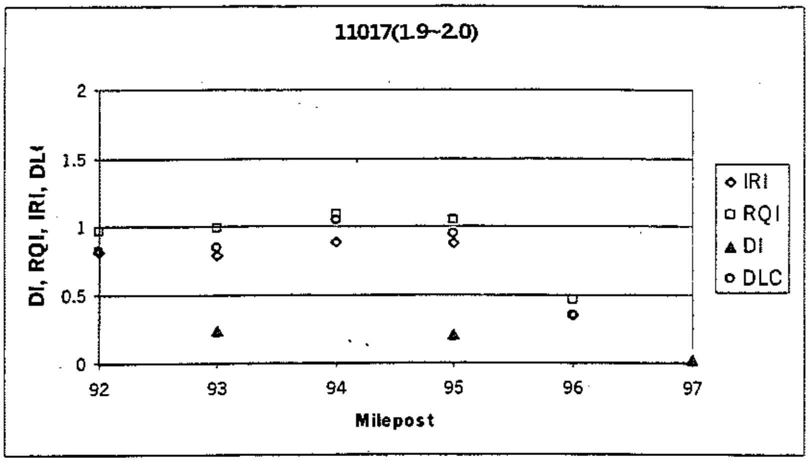


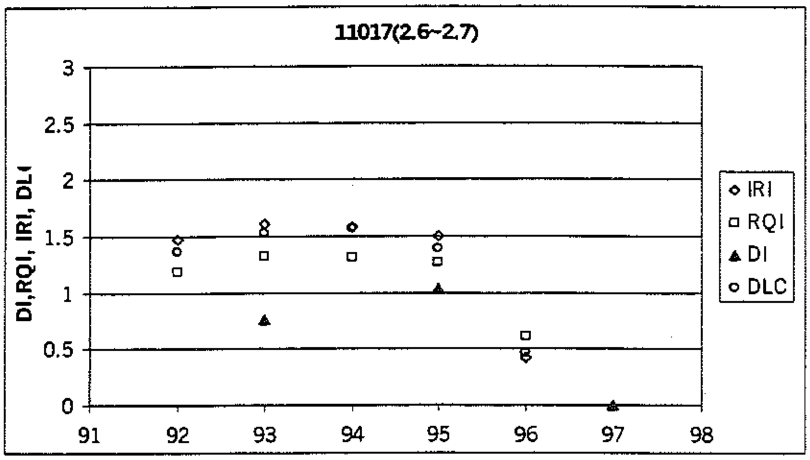


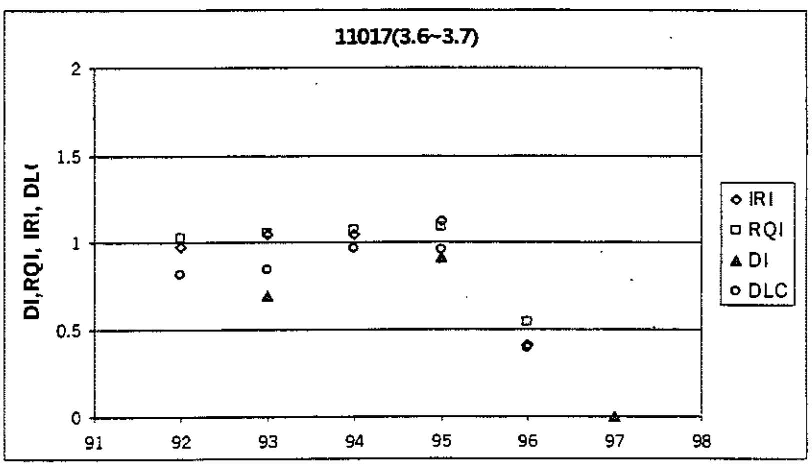


Distress and Roughness Profile along the Project Length for EB US-10 (CS 09101)

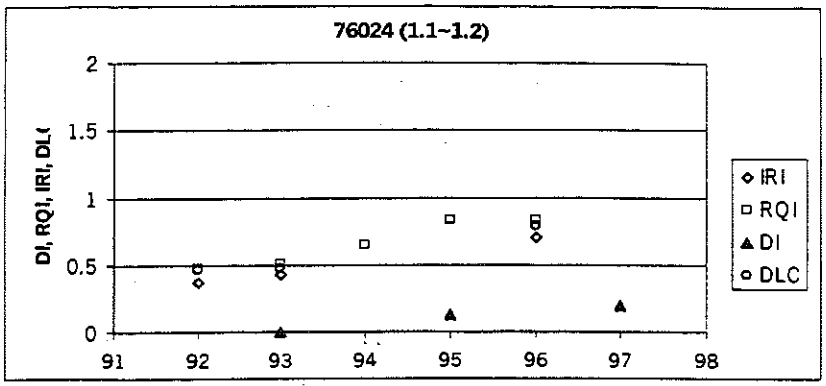


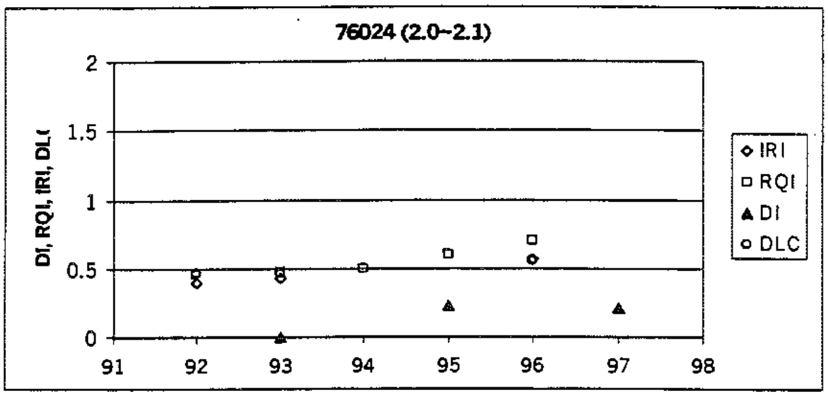


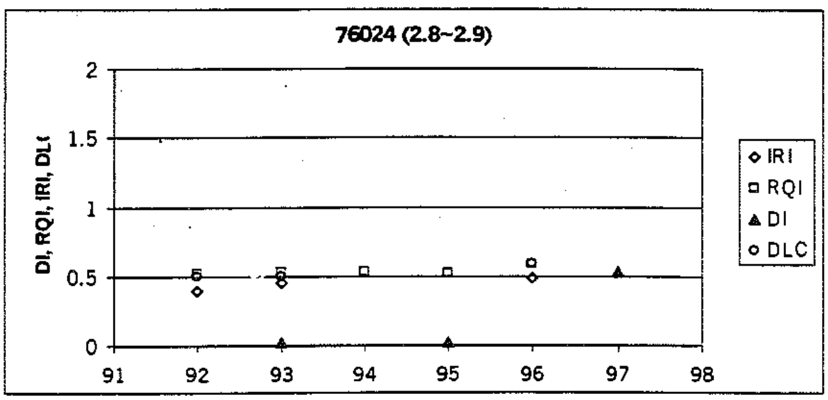


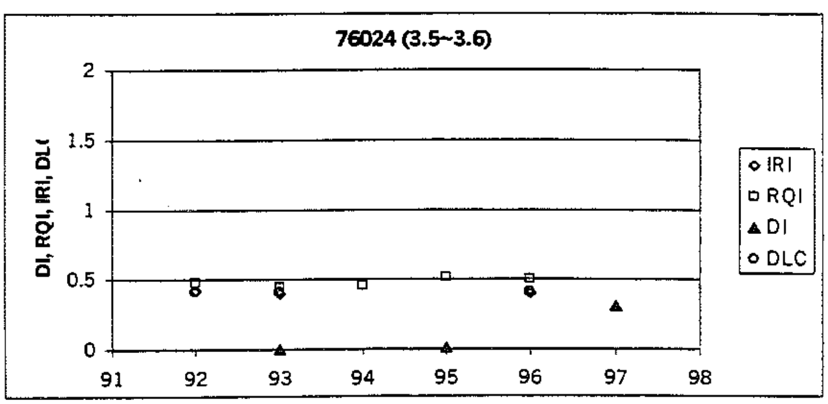


Year-to-Year Trend of Roughness, Distress and Dynamic Loading Indices for Four 0.1 Mile Sections along EB I-94 Project (CS 11017)

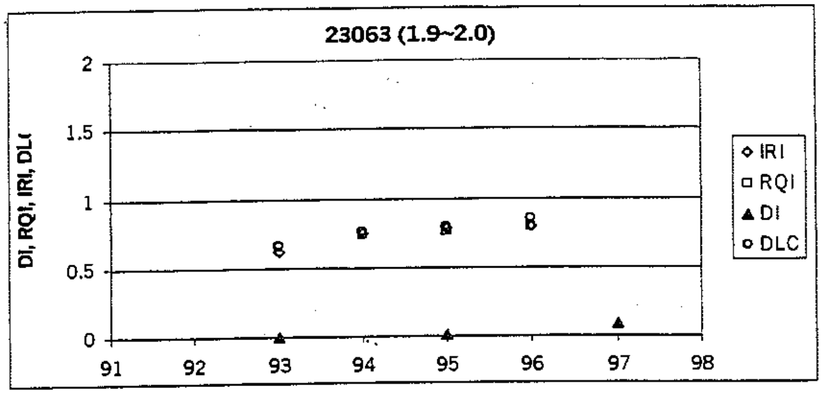


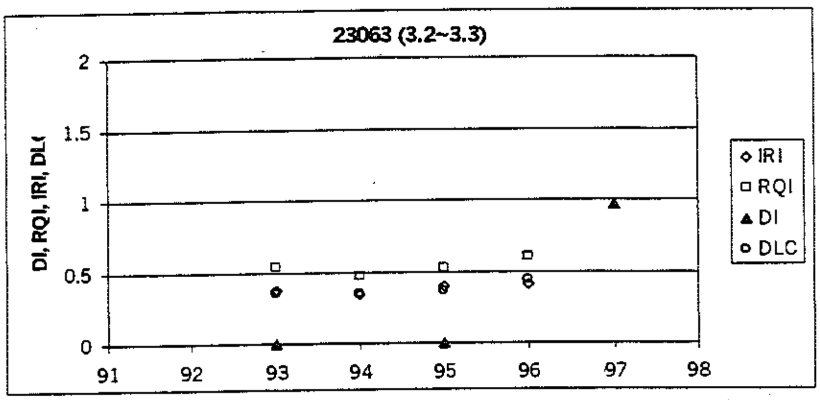


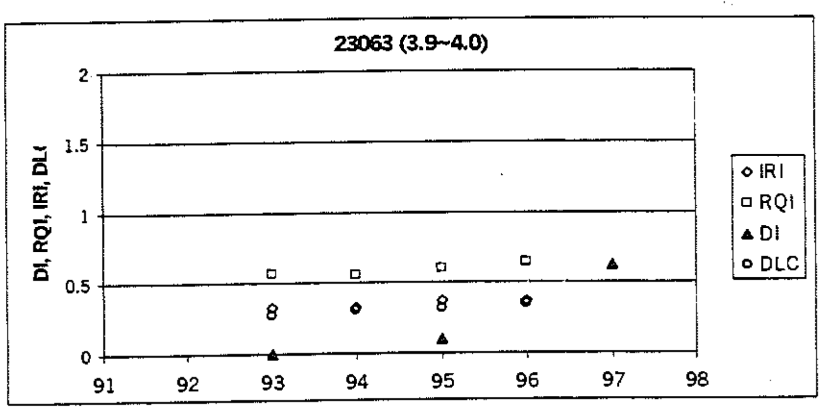


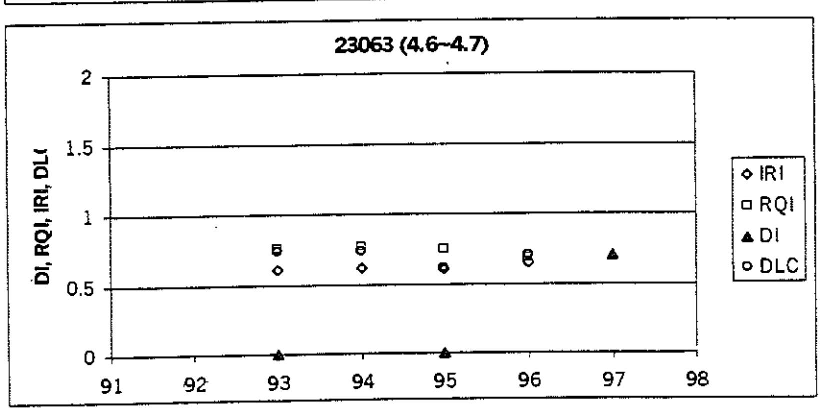


Year-to-Year Trend of Roughness, Distress and Dynamic Loading Indices for Four 0.1 Mile Sections along EB I-69 Project (CS 76024)

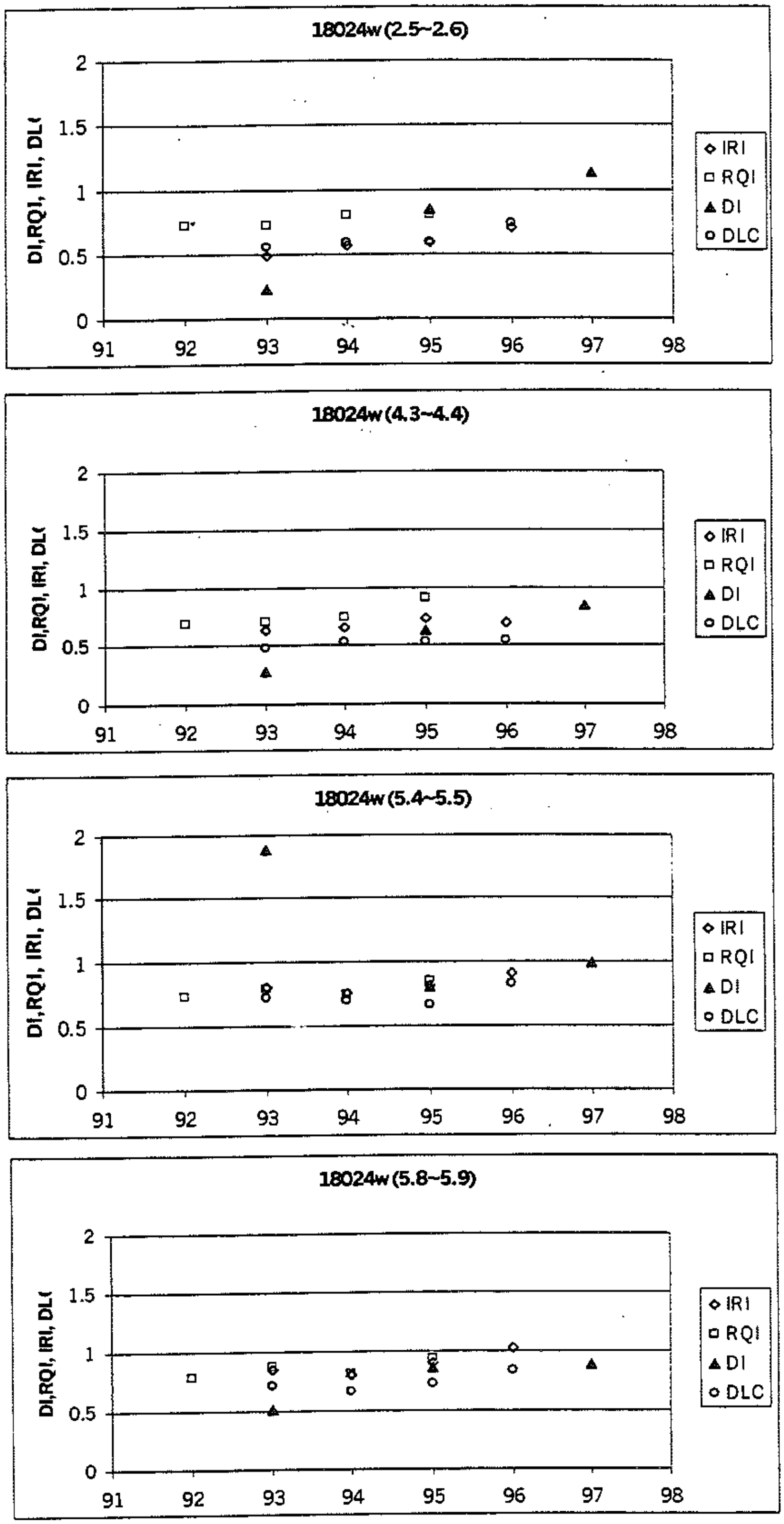




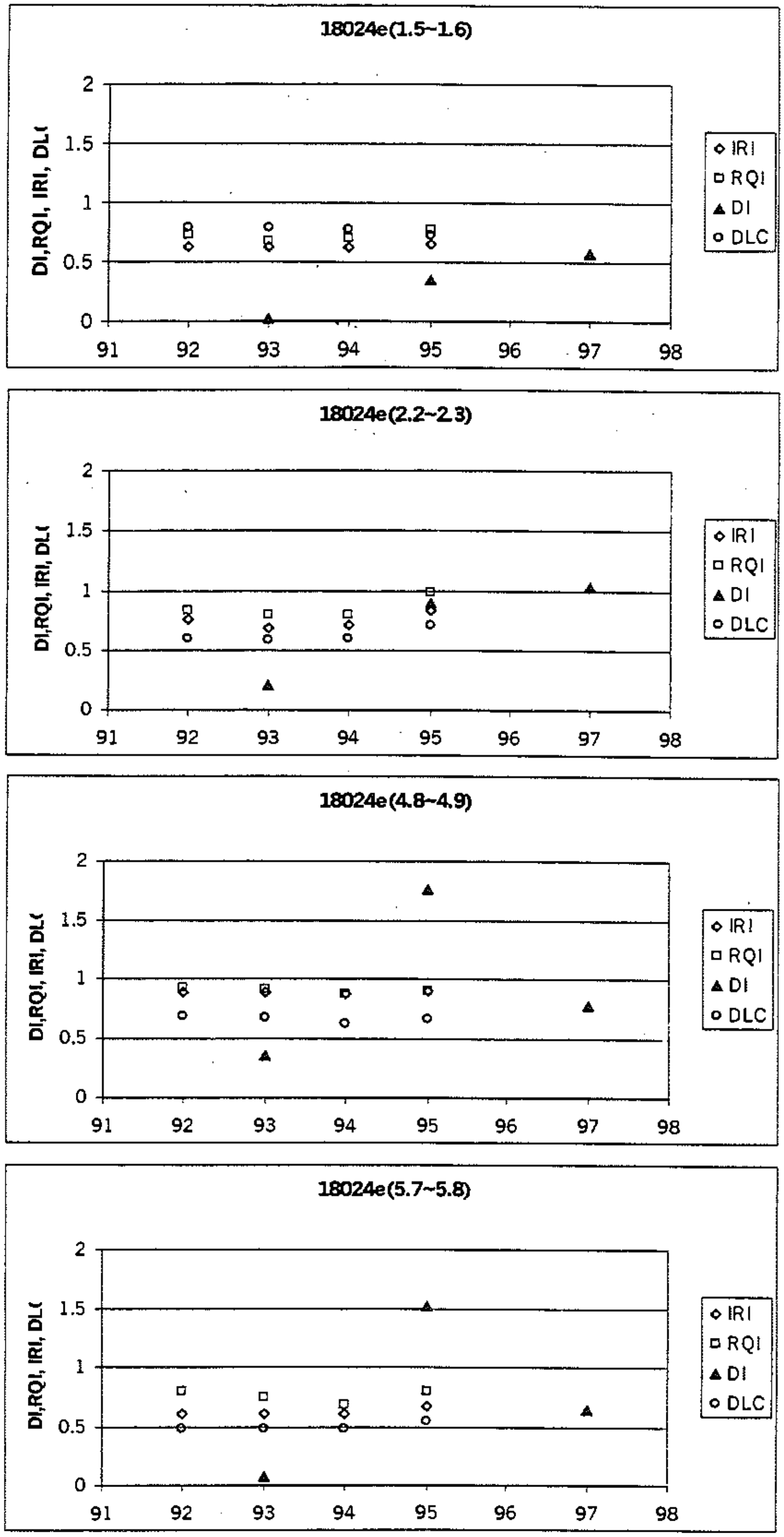




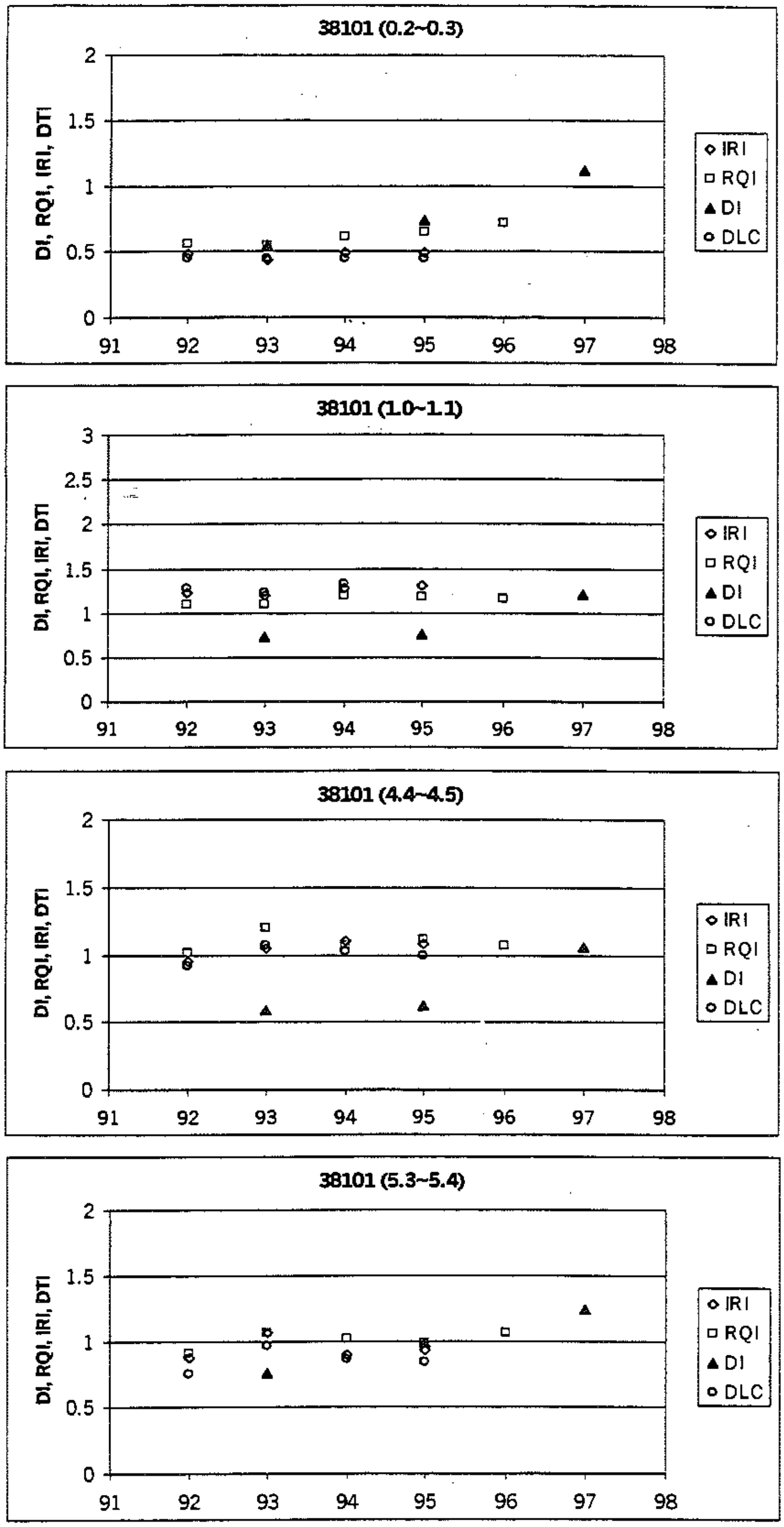
Year-to-Year Trend of Roughness, Distress and Dynamic Loading Indices for Four 0.1 Mile Sections along NB I-69 Project (CS 23063)



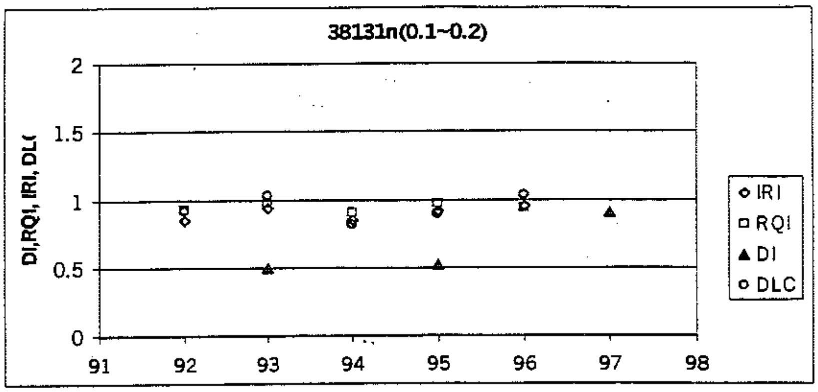
Year-to-Year Trend of Roughness, Distress and Dynamic Loading Indices for Four 0.1 Mile Sections along WB US-10 Project (CS 18024)

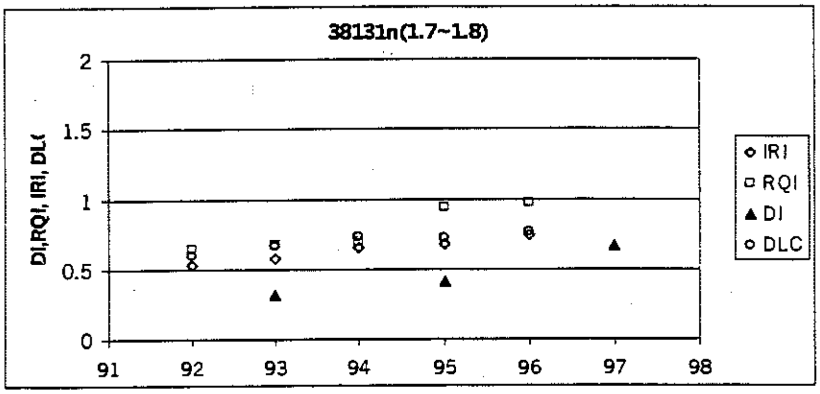


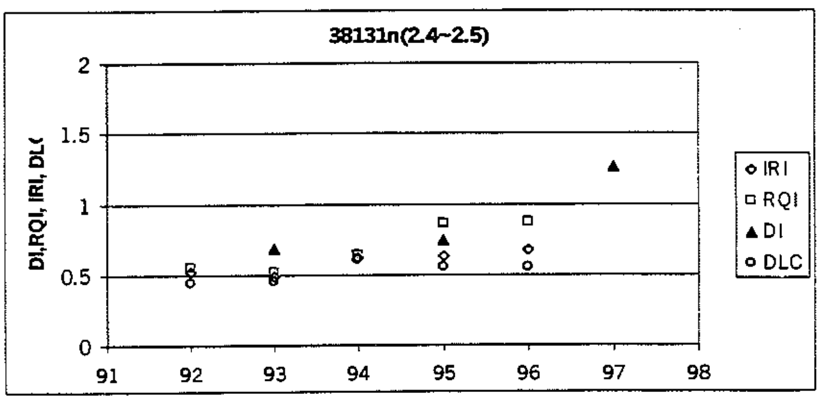
Year-to-Year Trend of Roughness, Distress and Dynamic Loading Indices for Four 0.1 Mile Sections along EB US-10 Project (CS 18024)

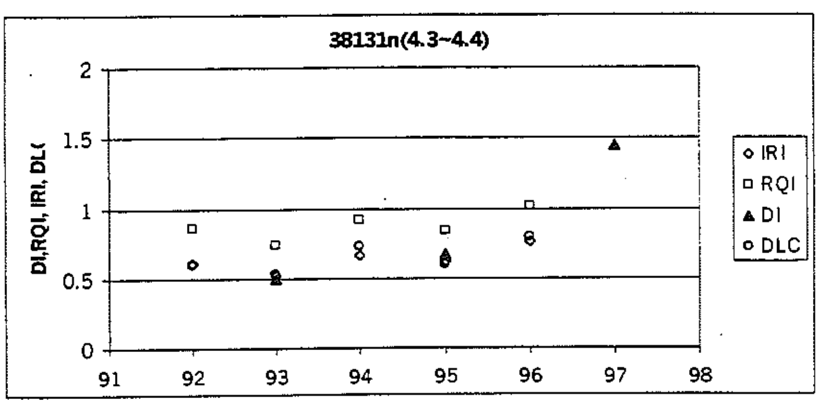


Year-to-Year Trend of Roughness, Distress and Dynamic Loading Indices for Four 0.1 Mile Sections along EB I-94 Project (CS 38101)

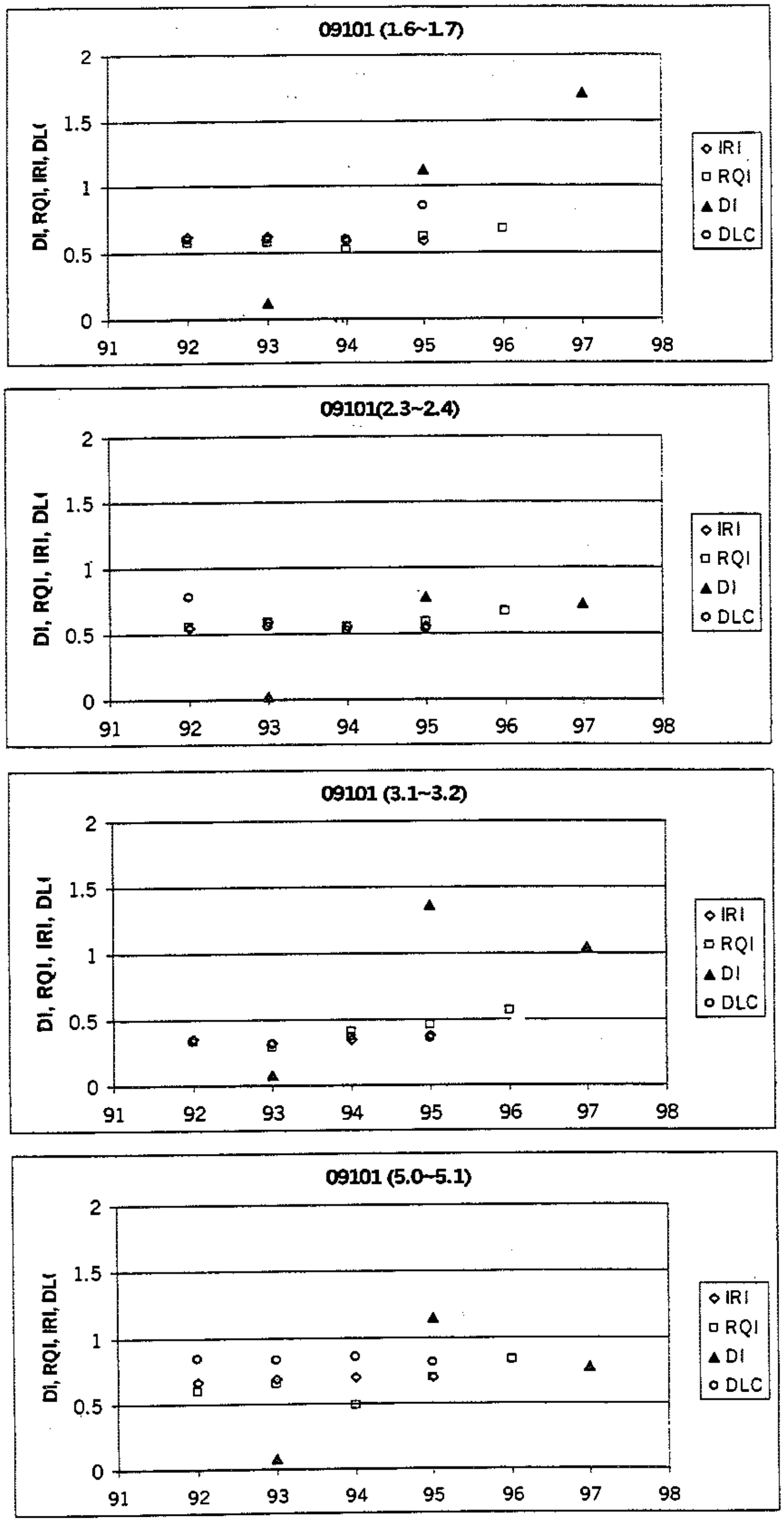




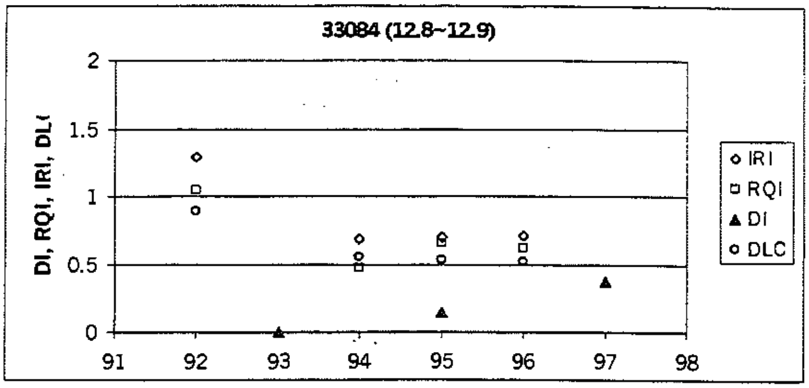


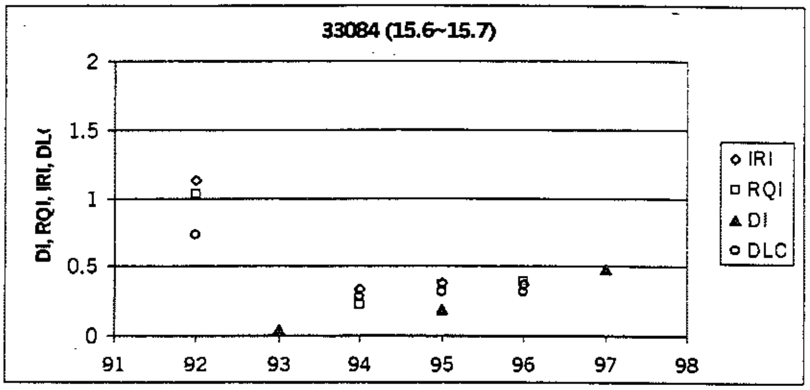


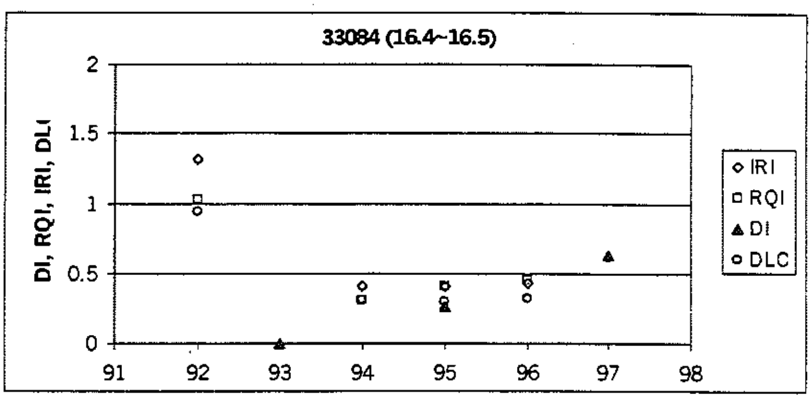
Year-to-Year Trend of Roughness, Distress and Dynamic Loading Indices for Four 0.1 Mile Sections along NB US-127 Project (CS 38131)

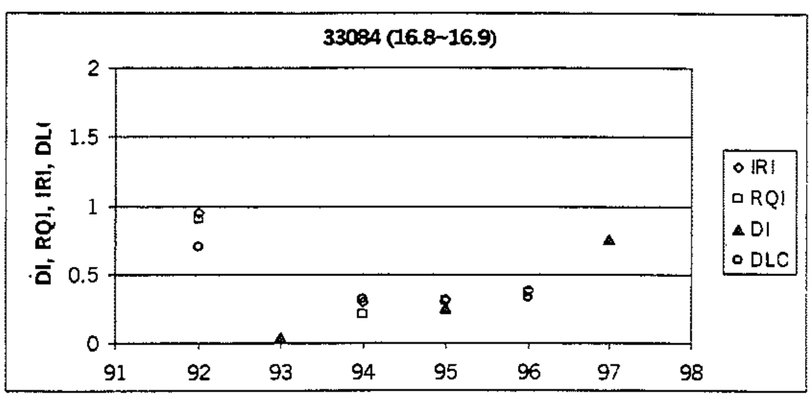


Year-to-Year Trend of Roughness, Distress and Dynamic Loading Indices for Four 0.1 Mile Sections along EB US-10 Project (CS 09101)

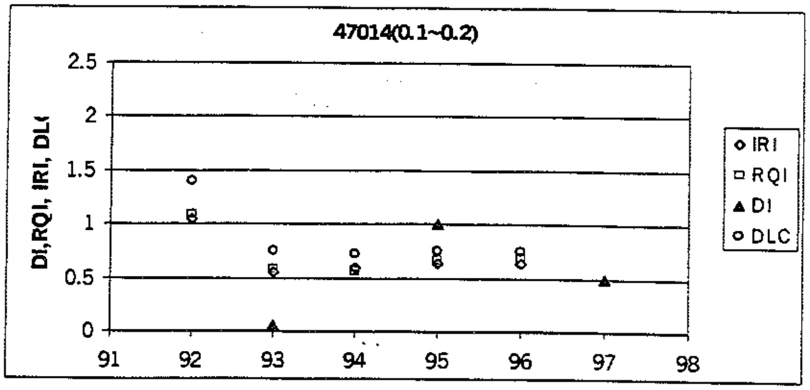


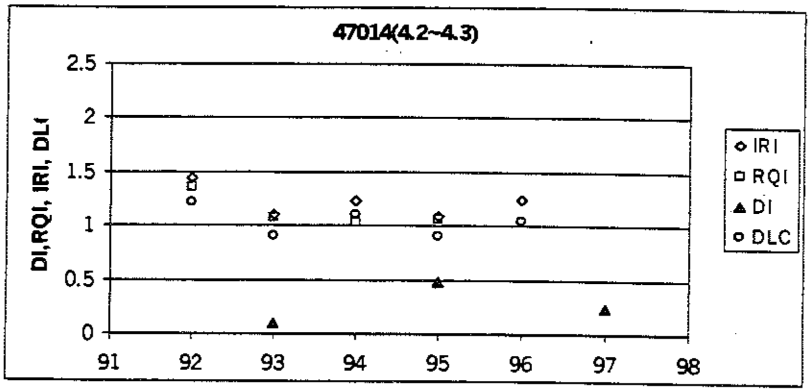




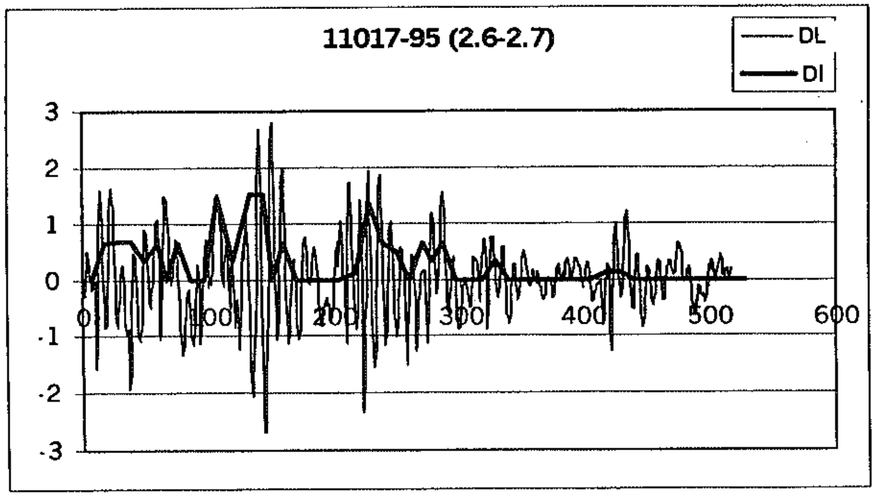


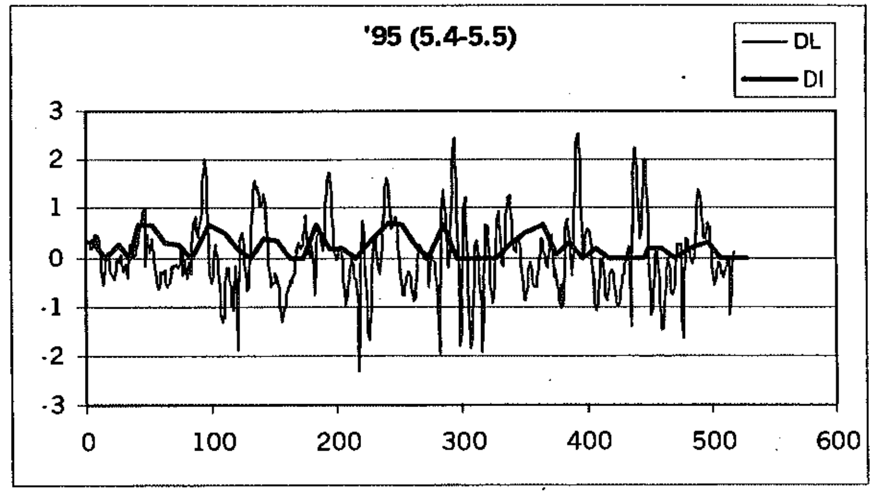
Year-to-Year Trend of Roughness, Distress and Dynamic Loading Indices for Four 0.1 Mile Sections along EB I-96 Project (CS 33084)

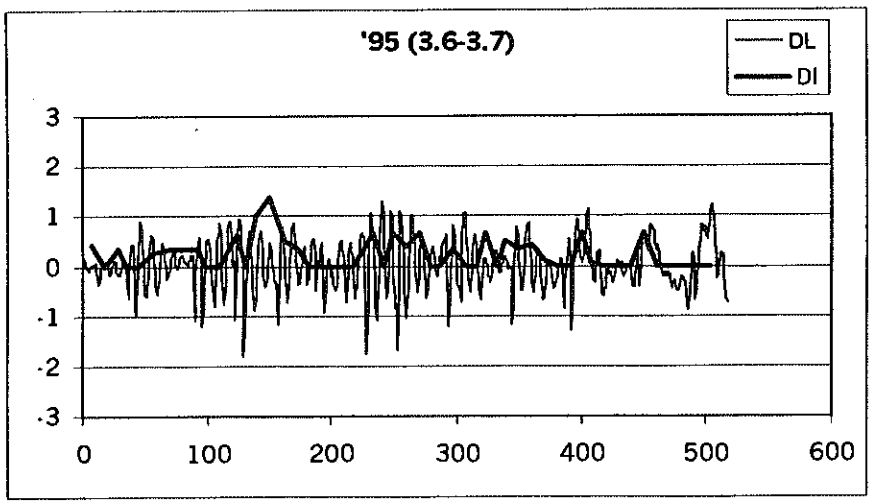




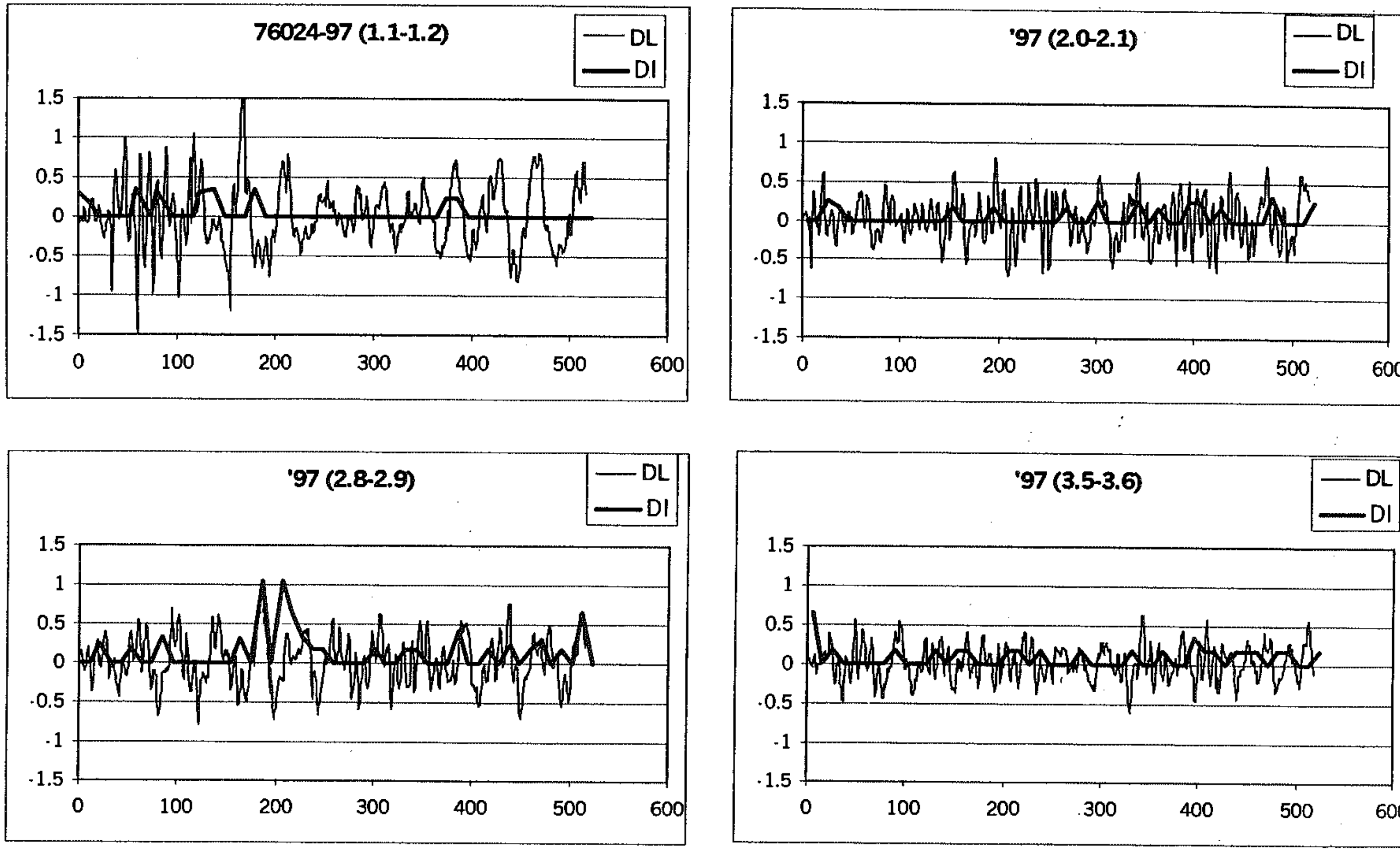
Year-to-Year Trend of Roughness, Distress and Dynamic Loading Indices for Four 0.1 Mile Sections along NB US-23 Project (CS 47014)



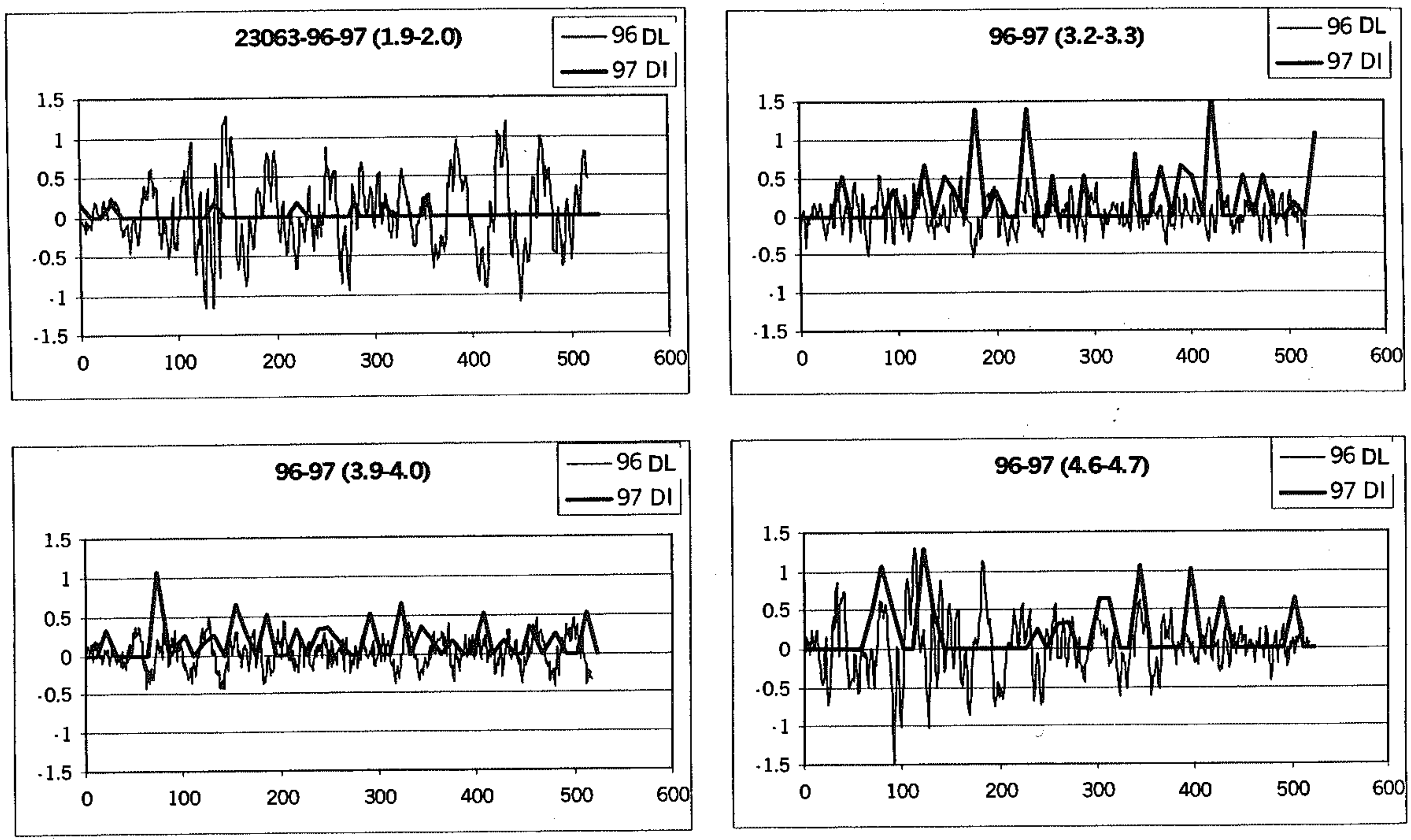




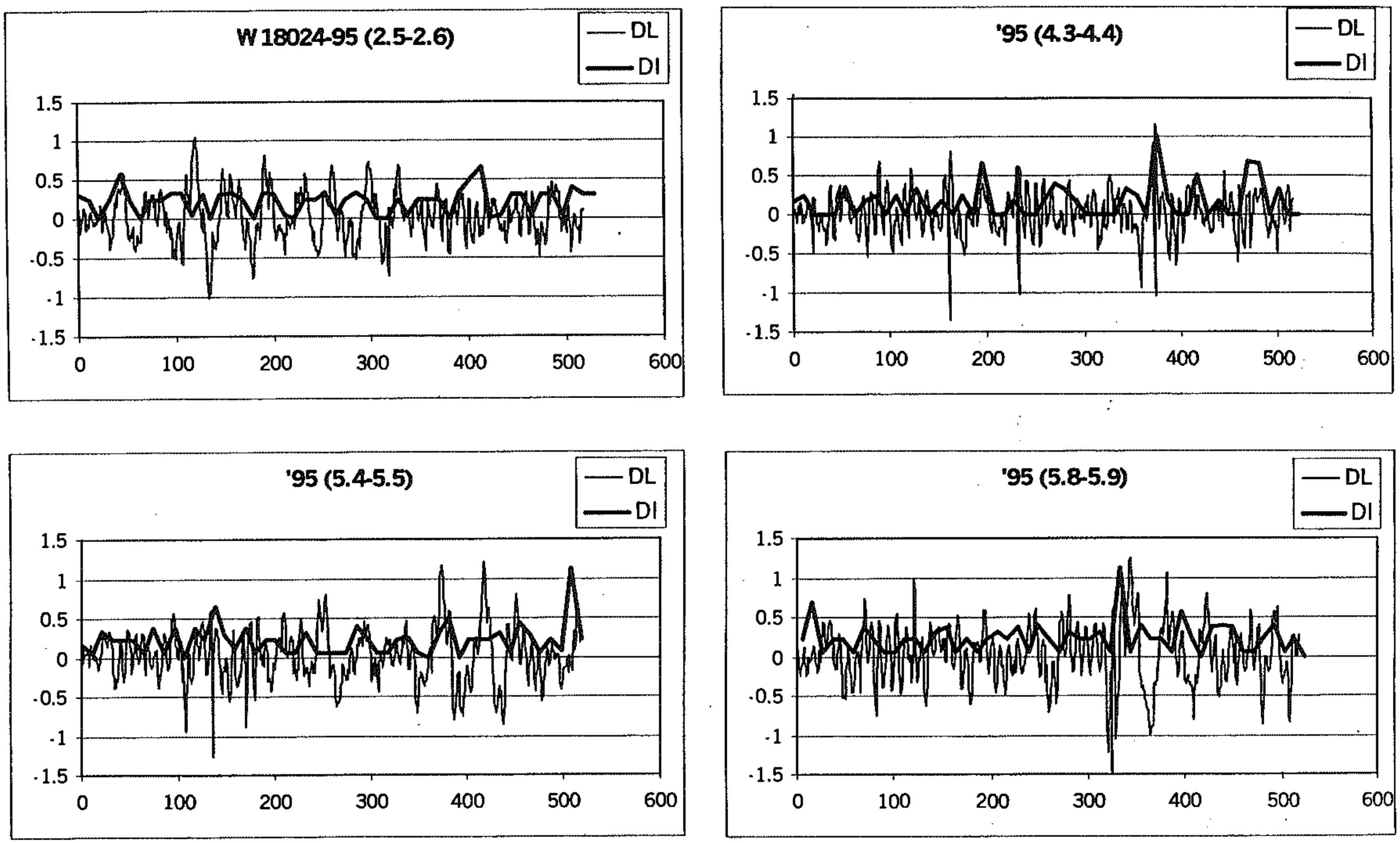
Normalized Dynamic Load and Distress Points versus Longitudinal Distance of EB I-94 Project (CS 11017)



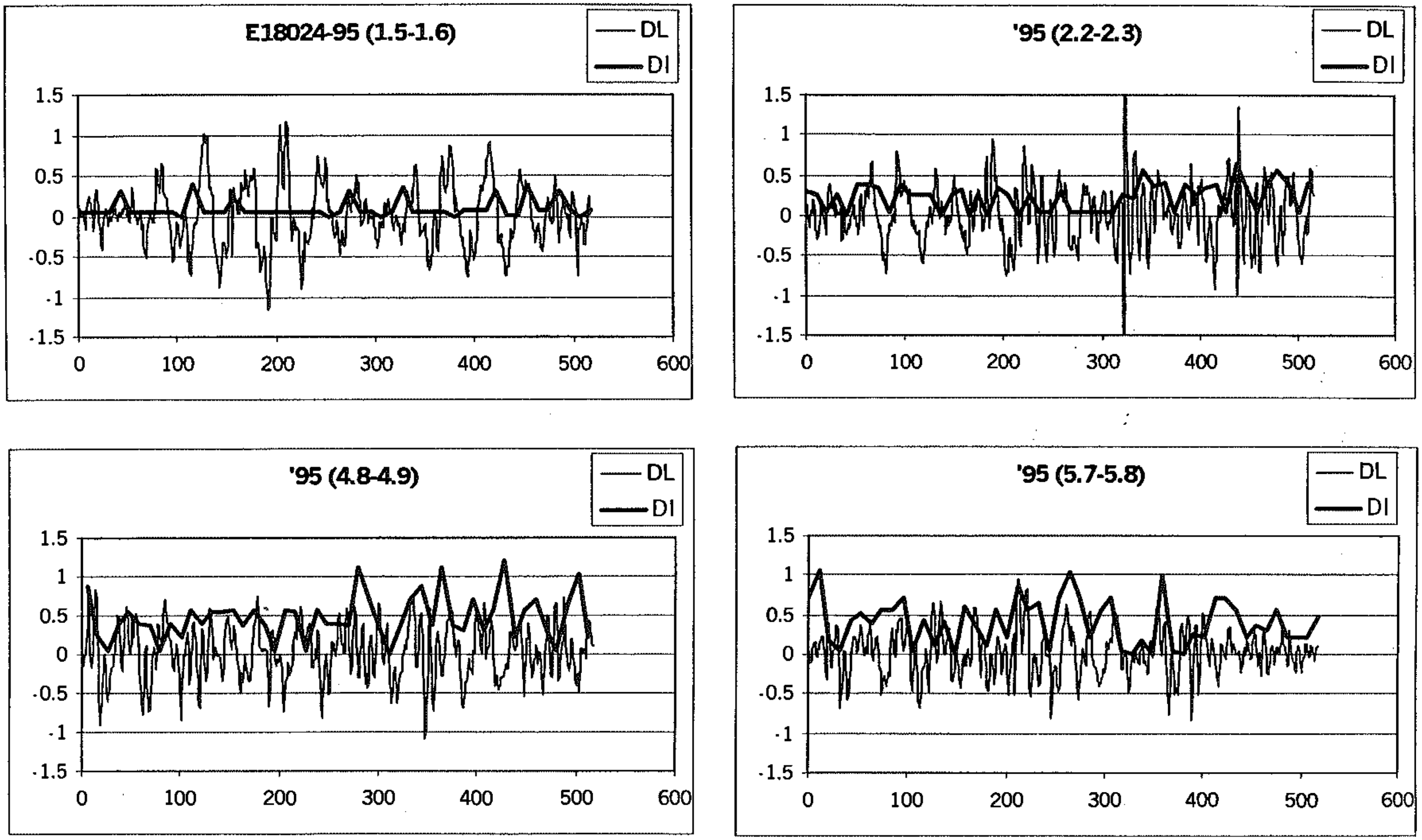
Normalized Dynamic Load and Distress Points versus Longitudinal Distance of EB I-69 Project (CS 76024)



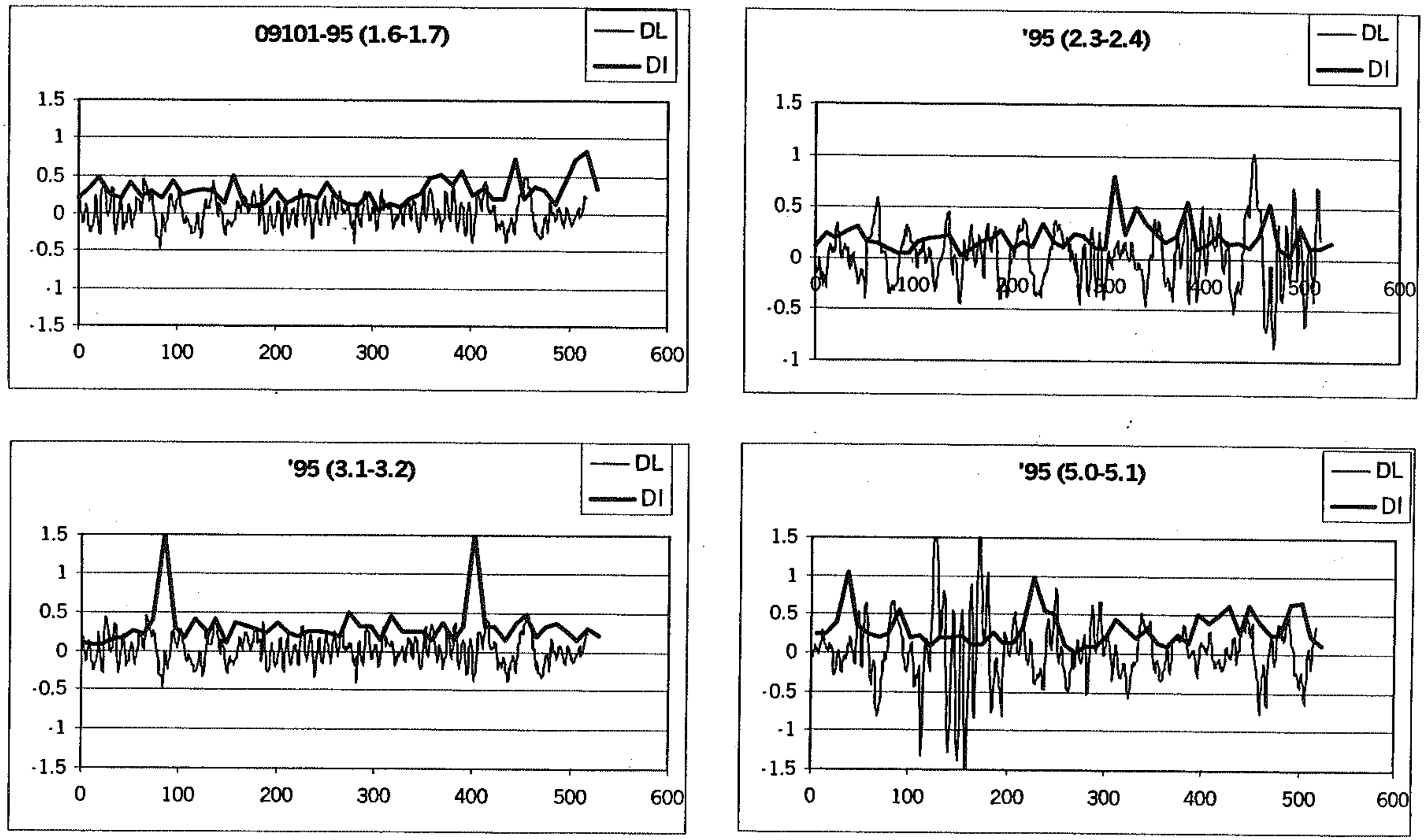
Normalized Dynamic Load and Distress Points versus Longitudinal Distance of NB I-69 Project (CS 23063)



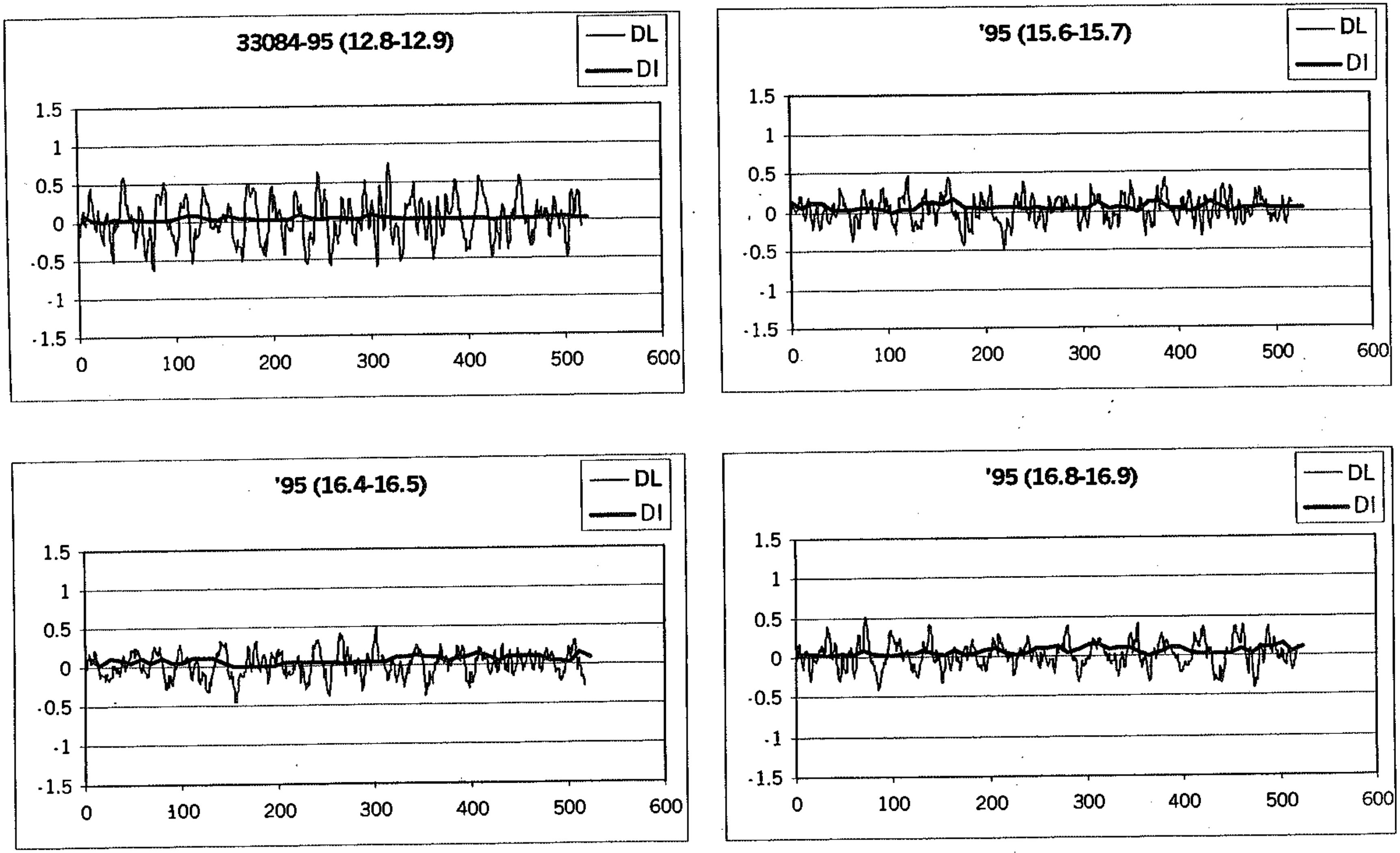
Normalized Dynamic Load and Distress Points versus Longitudinal Distance of WB US-10 Project (CS 18024)



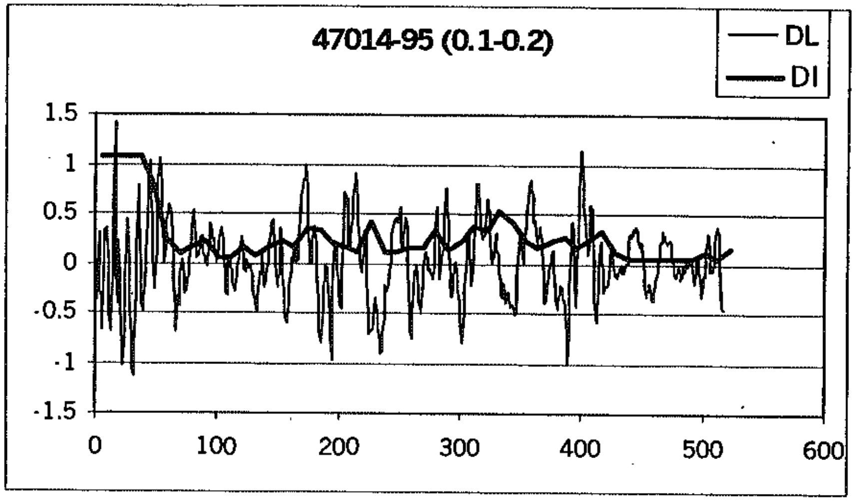
Normalized Dynamic Load and Distress Points versus Longitudinal Distance of EB US-10 Project (CS 18024)

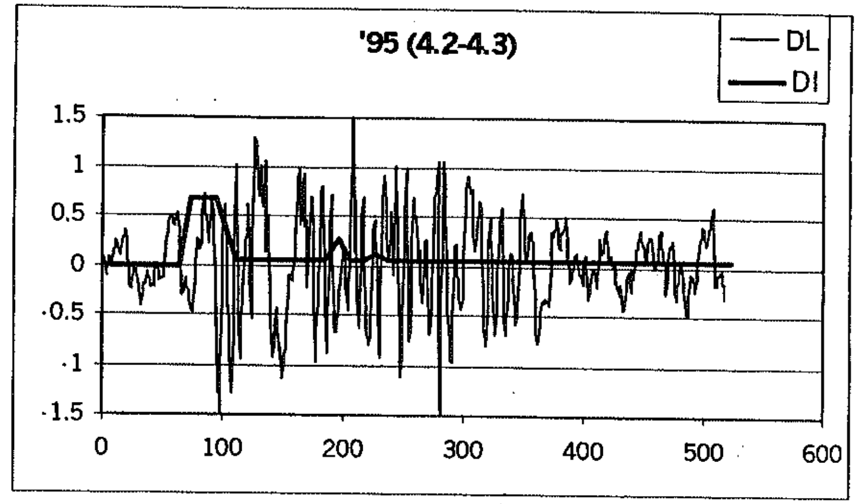


Normalized Dynamic Load and Distress Points versus Longitudinal Distance of EB US-10 Project (CS 09101)

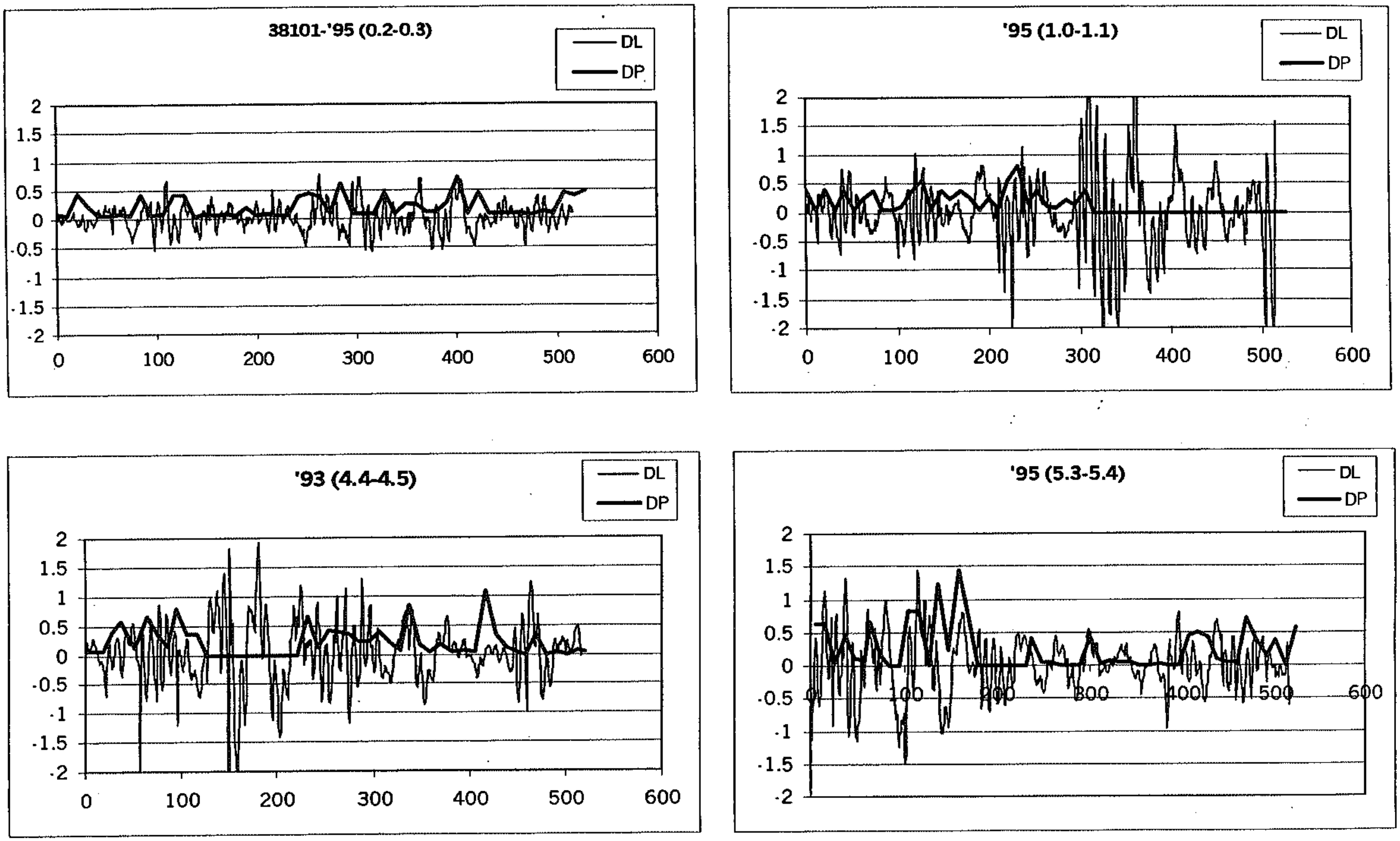


Normalized Dynamic Load and Distress Points versus Longitudinal Distance of EB I-96 Project (CS 33084)

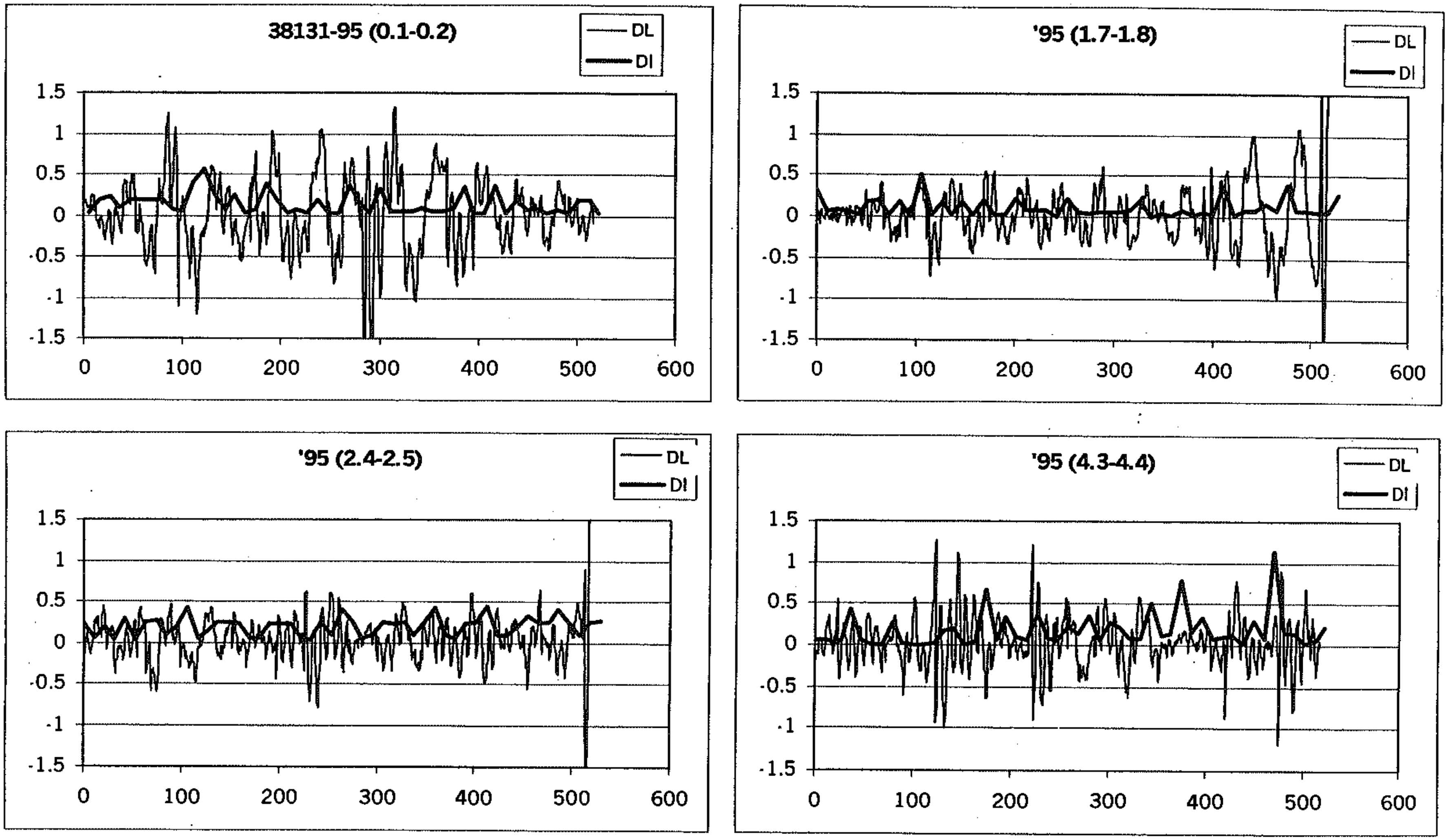




Normalized Dynamic Load and Distress Points versus Longitudinal Distance of NB US-23 Project (CS 47014)



Normalized Dynamic Load and Distress Points versus Longitudinal Distance of EB I-94 Project (CS 38101)



Normalized Dynamic Load and Distress Points versus Longitudinal Distance of NB US-127 Project (CS 38131)

Coefficient of Correlation between Truck Load and Distress Point

Control Section	M.P.	Coefficient of Correlation
11017	2.6-2.7	0.547
	3.6-3.7	0.261
	5.4-5.5	0.331
76024	1.1-1.2	0.303
	2.0-2.1	0.385
	2.8-2.9	0.080
	3.5-3.6	0.100
23063	1.9-2.0	0.247
	3.9-4.0	0.031
	3.2-3.3	0.111
	4.6-4.7	0.119
W18024	2.5-2.6	0.070
	4.3-4.4	0.172
	5.4-5.5	0.180
	5.8-5.9	0.213
E18024	1.5-1.6	0.342
	2.2-2.3	0.261
	4.8-4.9	0.211
	5.7-5.8	0.213
09101	1.6-1.7	0.122
	2.3-2.4	0.020
	3.1-3.2	-0.081
	5.0-5.1	-0.081
33084	12.8-12.9	0.218
	15.6-15.7	0.194
	16.4-16.5	-0.048
	16.8-16.9	0.204
47014	0.1-0.2	0.187
	4.2-4.3	0.452
38101	0.2-0.3	0.482
	1.0-1.1	0.187
	4.4-4.5	0.204
	5.3-5.4	0.284
38131	0.1-0.2	0.180
	1.7-1.8	0.181
	2.4-2.5	0.110
	4.3-4.4	0.203

APPENDIX H
DLI Computer Program Fortran Code

DLI Computer Program Fortran Code

```
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      CHARACTER*15   FILEIN, FILEOUT
      COMPLEX*8 PCOMPLEX(524289),PCOMPLEX1(524289)
      COMMON/INPUT1/N,  X,  DTIME,  FREQ(524289),  AMPL(524289),  AREA1,
     .             AREA2,  P1(1048577),  X1,  X2,  X3,X4,FREQ1(524289)
      DIMENSION P(1048577),INV(524289),S(524289)
$     DEBUG
C
C
C     FOR COMPOSITE AND FLEXIBLE
C
      WRITE(*,'(A,$)') ' ENTER INPUT FILENAME FOR PROFILE: '
      READ(*,'(A)') FILEIN
      WRITE(*,'(A,$)') ' ENTER OUTPUT FILENAME: '
      READ(*,'(A)') FILEOUT
      OPEN (4, FILE=FILEIN, STATUS='OLD')
      OPEN (6, FILE=FILEOUT, STATUS='UNKNOWN')
      DO I=1,600000
      READ(4,30,END=20) P(I)
      ENDDO
   20 K=I-1
      WRITE(*,'(A,I10)') ' Number of Data = ', K
      WRITE(6,'(A,I10)') 'Number of Data = ', K
      PI=4.*ATAN(1.)
      DTIME=0.25/88.0
C      DO 40 M=11,20
C         N=2**M
C         IF (N .LT. K) GO TO 40
C         GO TO 50
C   40 CONTINUE
C   50 CONTINUE
      X0=K/262144.0
      IF (X0 .LE. 1.0) THEN
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
                         C
C                  FILE NUMBER 8: 1.5Hz - 4.0 Hz
      C
C                    FILE NUMBER 9: 8 Hz - 15 Hz
      C
C
                         C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
          OPEN(8, STATUS='UNKNOWN', FORM='UNFORMATTED')
            OPEN(9, STATUS='UNKNOWN', FORM='UNFORMATTED')
            J=1
            REWIND (4)
            DO I=1,K
               READ (4,30) P(I)
            ENDDO
```

```
          DO I=K+1,262144
             P(I)=0.0
          ENDDO
          N=262144
        CALL AFFT (P,N,1,INV,S,IFERR)
        N2=N/2
        DO II=1,N2+1
           FREQ(II)=(II-1)/(N*DTIME)
           X=1.5*N*DTIME+1.0
           X1=4.0*N*DTIME+1.0
             X2=8.0*N*DTIME+1.0
           X3=15.0*N*DTIME+1.0
             JJ=INT(X)
           JJ1=INT(X1)
           JJ2=INT(X2)
           JJ3=INT(X3)
             JODD=2*II-1
           JEVEN=2*II
           PCOMPLEX(II)=DCMPLX(P(JODD),P(JEVEN))
             PCOMPLEX1(II)=DCMPLX(P(JODD),P(JEVEN))
        ENDDO
        DO II=1,JJ
           PCOMPLEX(II)=0.0
        ENDDO
          DO II=JJ1,N2+1
           PCOMPLEX(II)=0.0
        ENDDO
        DO II=1,N2+1
           JODD=2*II-1
           JEVEN=2*II
           P(JODD)=REAL(PCOMPLEX(II))
           P(JEVEN)=IMAG(PCOMPLEX(II))
        ENDDO
          CALL AFFT (P,N,-1,INV,S,IFERR)
        DO II=1,N
           WRITE(8) P(II)
        ENDDO

          DO II=1,JJ2
           PCOMPLEX1(II)=0.0
        ENDDO
            DO II=JJ3,N2+1
           PCOMPLEX1(II)=0.0
        ENDDO
          DO II=1,N2+1
           JODD=2*II-1
           JEVEN=2*II
           P(JODD)=REAL(PCOMPLEX1(II))
           P(JEVEN)=IMAG(PCOMPLEX1(II))
        ENDDO
          CALL AFFT (P,N,-1,INV,S,IFERR)
        DO II=1,N
           WRITE(9) P(II)
        ENDDO
          GOTO 501
    ENDIF
    IF (X0 .LE. 2.0) J=2
```

```
      IF (X0 .GT. 2.0) J=3
C
      OPEN(8, STATUS='UNKNOWN', FORM='UNFORMATTED')
      OPEN(9, STATUS='UNKNOWN', FORM='UNFORMATTED')
      REWIND (4)
      DO 500 I=1,J
         IF (I .EQ. 1) THEN
             N=262144
             N10=N
             DO III=1,N
                  READ(4,30) P(III)
             ENDDO
               CALL AFFT (P,N,1,INV,S,IFERR)
             N2=N/2
             DO II=1,N2+1
                FREQ(II)=(II-1)/(N*DTIME)
                X=1.5*N*DTIME+1.0
                X1=4.0*N*DTIME+1.0
                  X2=8.0*N*DTIME+1.0
                X3=15.0*N*DTIME+1.0
                  JJ=INT(X)
                JJ1=INT(X1)
                JJ2=INT(X2)
                JJ3=INT(X3)
                  JODD=2*II-1
                JEVEN=2*II
                PCOMPLEX(II)=DCMPLX(P(JODD),P(JEVEN))
                  PCOMPLEX1(II)=DCMPLX(P(JODD),P(JEVEN))
             ENDDO
             DO II=1,JJ
                PCOMPLEX(II)=0.0
             ENDDO
               DO II=JJ1,N2+1
                PCOMPLEX(II)=0.0
             ENDDO
             DO II=1,N2+1
                JODD=2*II-1
                JEVEN=2*II
                P(JODD)=REAL(PCOMPLEX(II))
                P(JEVEN)=IMAG(PCOMPLEX(II))
             ENDDO
               CALL AFFT (P,N,-1,INV,S,IFERR)
             DO II=1,N
                WRITE(8) P(II)
             ENDDO

               DO II=1,JJ2
                PCOMPLEX1(II)=0.0
             ENDDO
               DO II=JJ3,N2+1
                PCOMPLEX1(II)=0.0
             ENDDO
             DO II=1,N2+1
                JODD=2*II-1
                JEVEN=2*II
                P(JODD)=REAL(PCOMPLEX1(II))
                P(JEVEN)=IMAG(PCOMPLEX1(II))
```

```
           ENDDO
             CALL AFFT (P,N,-1,INV,S,IFERR)
           DO II=1,N
              WRITE(9) P(II)
           ENDDO
        ENDIF
C
        IF (I .EQ. 2) THEN
           K2=K-262144
           IF (K2 .GT. 262144) THEN
                K2=262144
                  N=262144
                  GO TO 50
             ENDIF
             DO 40 M=7,20
              N=2**M
              IF (N .LT. K2) GO TO 40
              GO TO 50
 40        CONTINUE
 50        CONTINUE
           N11=N10+N+1
           IF (K2 .EQ. N) THEN
                DO III=1,N
                   READ(4,30) P(III)
              ENDDO
                GO TO 61
           ENDIF
             DO III=1,K2
                READ(4,30) P(III)
           ENDDO
             DO 60 II=K2+1,N
              P(II)=0.0
 60        CONTINUE
 61          CALL AFFT (P,N,1,INV,S,IFERR)
           N2=N/2
           DO II=1,N2+1
              FREQ(II)=(II-1)/(N*DTIME)
              X=1.5*N*DTIME+1.0
              X1=4.0*N*DTIME+1.0
                X2=8.0*N*DTIME+1.0
              X3=15.0*N*DTIME+1.0
                JJ=INT(X)
              JJ1=INT(X1)
              JJ2=INT(X2)
              JJ3=INT(X3)
                JODD=2*II-1
              JEVEN=2*II
              PCOMPLEX(II)=DCMPLX(P(JODD),P(JEVEN))
                PCOMPLEX1(II)=DCMPLX(P(JODD),P(JEVEN))
            ENDDO
            DO II=1,JJ
               PCOMPLEX(II)=0.0
            ENDDO
              DO II=JJ1,N2+1
               PCOMPLEX(II)=0.0
            ENDDO
            DO II=1,N2+1
```

```
          JODD=2*II-1
          JEVEN=2*II
          P(JODD)=REAL(PCOMPLEX(II))
          P(JEVEN)=IMAG(PCOMPLEX(II))
       ENDDO
         CALL AFFT (P,N,-1,INV,S,IFERR)
       DO II=1,N
          WRITE(8) P(II)
       ENDDO

         DO II=1,JJ2
          PCOMPLEX1(II)=0.0
       ENDDO
         DO II=JJ3,N2+1
          PCOMPLEX1(II)=0.0
       ENDDO
       DO II=1,N2+1
          JODD=2*II-1
          JEVEN=2*II
          P(JODD)=REAL(PCOMPLEX1(II))
          P(JEVEN)=IMAG(PCOMPLEX1(II))
       ENDDO
         CALL AFFT (P,N,-1,INV,S,IFERR)
       DO II=1,N
          WRITE(9) P(II)
       ENDDO
    ENDIF
C
    IF (I .EQ. 3) THEN
       K3=K-K2-262144
       DO 200 M=7,20
          N=2**M
          IF (N .LT. K3) GO TO 200
          GO TO 210
200    CONTINUE
210    CONTINUE
       IF (K3 .EQ. N) THEN
            DO III=1,N
                 READ (4,30) P(III)
              ENDDO
              GO TO 230
       ENDIF
         DO III=1,K3
                READ (4,30) P(III)
            ENDDO
           DO 220 II=K3+1,N
            P(II)=0.0
220      CONTINUE
230    CONTINUE
       N12=N11+N+1
       CALL AFFT (P,N,1,INV,S,IFERR)
       N2=N/2
       DO II=1,N2+1
          FREQ(II)=(II-1)/(N*DTIME)
          X=1.5*N*DTIME+1.0
          X1=4.0*N*DTIME+1.0
            X2=8.0*N*DTIME+1.0
```

```
          X3=15.0*N*DTIME+1.0
            JJ=INT(X)
          JJ1=INT(X1)
          JJ2=INT(X2)
          JJ3=INT(X3)
            JODD=2*II-1
          JEVEN=2*II
          PCOMPLEX(II)=DCMPLX(P(JODD),P(JEVEN))
            PCOMPLEX1(II)=DCMPLX(P(JODD),P(JEVEN))
       ENDDO
       DO II=1,JJ
          PCOMPLEX(II)=0.0
       ENDDO
         DO II=JJ1,N2+1
          PCOMPLEX(II)=0.0
       ENDDO
       DO II=1,N2+1
          JODD=2*II-1
          JEVEN=2*II
          P(JODD)=REAL(PCOMPLEX(II))
          P(JEVEN)=IMAG(PCOMPLEX(II))
       ENDDO
         CALL AFFT (P,N,-1,INV,S,IFERR)
       DO II=1,N
          WRITE(8) P(II)
       ENDDO

         DO II=1,JJ2
          PCOMPLEX1(II)=0.0
       ENDDO
         DO II=JJ3,N2+1
          PCOMPLEX1(II)=0.0
       ENDDO
       DO II=1,N2+1
          JODD=2*II-1
          JEVEN=2*II
          P(JODD)=REAL(PCOMPLEX1(II))
          P(JEVEN)=IMAG(PCOMPLEX1(II))
       ENDDO
         CALL AFFT (P,N,-1,INV,S,IFERR)
       DO II=1,N
          WRITE(9) P(II)
       ENDDO
    ENDIF
500 CONTINUE
501 CONTINUE
    REWIND (8)
    REWIND (9)
    REWIND (8)
    WRITE (6,'(A)') '      MP          STD(1)        STD(2)        DLI '
    J2=INT(K/2112)*2112
    J=1
    I=1
600 X=0.0
    X3=0.0
    SUMX=0.0
    SUMX1=0.0
```

```
  605 READ(8) P(I)
      READ(9) P1(I)
      SUMX=SUMX+P(I)
      X=X+P(I)**2
      SUMX1=SUMX1+P1(I)
      X3=X3+P1(I)**2
      J1=J*2112
      IF (I .EQ. J1) GOTO 610
      I=I+1
      GOTO 605
  610 XMEAN=SUMX/2112.0
      XMEANS=XMEAN**2
      XMEAN1=SUMX1/2112.0
      XMEANS1=XMEAN1**2
      VAR1=(X-2112*XMEANS)/(2112-1)
      VAR2=(X3-2112*XMEANS1)/(2112-1)
      DLI=SQRT((VAR1+VAR2*14.0))
      X1=J/10.0
      X2=X1-0.1
      WRITE(6,620) X2,' - ',X1, DLI
      J=J+1
      IF (I .LT. J2) GOTO 600
  620 FORMAT (F4.1,A,F4.1,F10.5)
   30 FORMAT (F12.9)
   80 FORMAT (3(F15.6))
      END

      SUBROUTINE AFFT(A,N,KEY,INV,S,IFERR)
C     FAST FOURIER TRANSFORM OF REAL ARRAY(RADIX-2)
C     REQUIRES SUBROUTINES FFT,RFFT,RFSN
C     CODED BY JOHN LYSMER - FEBRUARY 1974 (VERSION 1.29.75)
C
C     INPUT VARIABLES (WHEN KEY=1)
C     A(J)    = REAL ARRAY CONTAINING INPUT FUNCTION - TIME DOMAIN
C               MINIMUM DIMENSION = N+4
C     N       = LENGTH OF A(J) - MUST BE POWER OF 2 - MUST BE .GE. 8
C     KEY     =    1 INDICATES FORWARD TRANSFORM
C               -1 INDICATES INVERSE TRANSFORM
C     INV(J)  = SCRATCH ARRAY - MINIMUM DIMENSION = N/8+1
C     S(J)    = SCRATCH ARRAY - MINIMUM DIMENSION = N/8+1
C
C     OUTPUT VARIABLES (WHEN KEY=1)
C     A(K)    = FOURIER TRANSFORM OF A(J) ABOVE - FREQUENCY DOMAIN
C               A(2*J+1) CONTAINS THE REAL PARTS, AND
C               A(2*J+2) CONTAINS THE IMAGINARY PARTS OF
C               THE COMPLEX AMPLITUDES OF THE FOURIER EXPANSION
C               A(T) = SUM(REAL PART OF(AMPLITUDE*EXP(I*OMEGA(J)*T)))
C               WHERE J RUNS FROM ZERO TO N/2
C     IFERR   = 0 INDICATES NORMAL RETURN
C             = 1 INDICATES ERROR RETURN
C
C     WHEN KEY = -1 THE A(J)-DESCRIPTIONS UNDER INPUT AND OUTPUT
C     VARIABLES SHOULD BE INTERCHANGED
C     IN BOTH CASES N REMAINS THE NUMBER OF POINTS IN THE TIME DOMAIN
C
C     REAL*8 A,INV,S
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
```

```
      DIMENSION A(1),INV(1),S(1)
C
C     CHECK N AND COMPUTE M
C
      IF(N.LT.1) GO TO 2
      IFERR=0
      I=N
      M=0
    1 J=I
      I=I/2
      IF(J.NE.2*I) GO TO 2
      IF(I.EQ.1) GO TO 3
      M=M+1
      GO TO 1
    2 IFERR=1
      PRINT 1000,N
      RETURN
    3 IF(M.LT.2) GO TO 2
C
C     FORWARD TRANSFORM FOR N.GE.8
C
      IF(KEY.EQ.-1) GO TO 5
      CALL RFFT(A,M,INV,S,IFERR,1)
      RETURN
C
C     INVERSE TRANSFORM FOR N.GE.8
C
    5 CALL RFSN(A,M,INV,S,IFERR,-1)
      RETURN
C
 1000 FORMAT(3H0N=,I5,25H ILLEGAL ARGUMENT TO AFFT)
      END
      SUBROUTINE FFT (A,M,INV,S,IFSET,IFERR)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C     REAL*8 A,S,W,W2,W3
      DIMENSION A(1),INV(1),S(1),N(3),M(3),NP(3),W(2),W2(2),W3(2)
      EQUIVALENCE (N1,N(1)), (N2,N(2)), (N3,N(3))
      M1=M(1)
      M2=M(2)
      M3=M(3)
      MTT=M1-2
      MT=MAX0(2,MTT)
      NT=2**MT
10    IF (IABS(IFSET)-1) 610,610,20
610   MT=MAX0(M(1),M(2),M(3))-2
      MT=MAX0(2,MT)
      IF (MT-20) 630,630,620
620   IFERR=1
      GO TO 600
630   IFERR=0
      NT=2**MT
      NTV2=NT/2
      THETA=.7853981634
      JSTEP=NT
      JDIF=NTV2
      S(JDIF)=SIN(THETA)
      DO 660 L=2,MT
```

```
      THETA=THETA/2.
      JSTEP2=JSTEP
      JSTEP=JDIF
      JDIF=JSTEP/2
      S(JDIF)=SIN(THETA)
      JC1=NT-JDIF
      S(JC1)=COS(THETA)
      JLAST=NT-JSTEP2
      IF (JLAST-JSTEP) 660,640,640
640   DO 650 J=JSTEP,JLAST,JSTEP
      JC=NT-J
      JD=J+JDIF
650   S(JD)=S(J)*S(JC1)+S(JDIF)*S(JC)
660   CONTINUE
C
C     SET UP INV(J) TABLE
      MTLEXP=NTV2
      LM1EXP=1
      INV(1)=0
      DO 680 L=1,MT
      INV(LM1EXP+1)=MTLEXP
      DO 670 J=2,LM1EXP
      JJ=J+LM1EXP
670   INV(JJ)=INV(J)+MTLEXP
      MTLEXP=MTLEXP/2
680   LM1EXP=LM1EXP*2
      IF (IFSET) 20,600,20
20    MTT=MAX0(M(1),M(2),M(3))-2
      ROOT2=SQRT(2.)
      IF (MTT-MT) 40,40,30
30    IFERR=1
      PRINT 1000
      STOP
 1000 FORMAT(31H --- ERROR IN FOURIER TRANSFORM  )
40    IFERR=0
C     M1=M(1)
C     M2=M(2)
C     M3=M(3)
      N1=2**M1
      N2=2**M2
      N3=2**M3
      IF (IFSET) 50,50,70
50    NX=N1*N2*N3
      FN=NX
      DO 60 I=1,NX
      A(2*I-1)=A(2*I-1)/FN
60    A(2*I)=-A(2*I)/FN
70    NP(1)=N1*2
      NP(2)=NP(1)*N2
      NP(3)=NP(2)*N3
      DO 330 ID=1,3
      IL=NP(3)-NP(ID)
      IL1=IL+1
      MI=M(ID)
      IF (MI) 330,330,80
80    IDIF=NP(ID)
      KBIT=NP(ID)
```

```
      MEV=2*(MI/2)
      IF (MI-MEV) 120,120,90
 90   KBIT=KBIT/2
      KL=KBIT-2
      DO 100 I=1,IL1,IDIF
      KLAST=KL+I
      DO 100 K=I,KLAST,2
      KD=K+KBIT
      T=A(KD)
      A(KD)=A(K)-T
      A(K)=A(K)+T
      T=A(KD+1)
      A(KD+1)=A(K+1)-T
100   A(K+1)=A(K+1)+T
      IF (MI-1) 330,330,110
110   LFIRST=3
      JLAST=1
      GO TO 130
120   LFIRST=2
      JLAST=0
130   DO 320 L=LFIRST,MI,2
      JJDIF=KBIT
      KBIT=KBIT/4
      KL=KBIT-2
      DO 140 I=1,IL1,IDIF
      KLAST=I+KL
      DO 140 K=I,KLAST,2
      K1=K+KBIT
      K2=K1+KBIT
      K3=K2+KBIT
      T=A(K2)
      A(K2)=A(K)-T
      A(K)=A(K)+T
      T=A(K2+1)
      A(K2+1)=A(K+1)-T
      A(K+1)=A(K+1)+T
      T=A(K3)
      A(K3)=A(K1)-T
      A(K1)=A(K1)+T
      T=A(K3+1)
      A(K3+1)=A(K1+1)-T
      A(K1+1)=A(K1+1)+T
      T=A(K1)
      A(K1)=A(K)-T
      A(K)=A(K)+T
      T=A(K1+1)
      A(K1+1)=A(K+1)-T
      A(K+1)=A(K+1)+T
      R=-A(K3+1)
      T=A(K3)
      A(K3)=A(K2)-R
      A(K2)=A(K2)+R
      A(K3+1)=A(K2+1)-T
140   A(K2+1)=A(K2+1)+T
      IF (JLAST) 310,310,150
150   JJ=JJDIF+1
      ILAST=IL+JJ
```

```
      DO 160 I=JJ,ILAST,IDIF
      KLAST=KL+I
      DO 160 K=I,KLAST,2
      K1=K+KBIT
      K2=K1+KBIT
      K3=K2+KBIT
      R=-A(K2+1)
      T=A(K2)
      A(K2)=A(K)-R
      A(K)=A(K)+R
      A(K2+1)=A(K+1)-T
      A(K+1)=A(K+1)+T
      AWR=A(K1)-A(K1+1)
      AWI=A(K1+1)+A(K1)
      R=-A(K3)-A(K3+1)
      T=A(K3)-A(K3+1)
      A(K3)=(AWR-R)/ROOT2
      A(K3+1)=(AWI-T)/ROOT2
      A(K1)=(AWR+R)/ROOT2
      A(K1+1)=(AWI+T)/ROOT2
      T=A(K1)
      A(K1)=A(K)-T
      A(K)=A(K)+T
      T=A(K1+1)
      A(K1+1)=A(K+1)-T
      A(K+1)=A(K+1)+T
      R=-A(K3+1)
      T=A(K3)
      A(K3)=A(K2)-R
      A(K2)=A(K2)+R
      A(K3+1)=A(K2+1)-T
160   A(K2+1)=A(K2+1)+T
      IF (JLAST-1) 310,310,170
170   JJ=JJ+JJDIF
      DO 300 J=2,JLAST
      I=INV(J+1)
      IC=NT-I
      W(1)=S(IC)
      W(2)=S(I)
      I2=2*I
      I2C=NT-I2
      IF (I2C) 200,190,180
180   W2(1)=S(I2C)
      W2(2)=S(I2)
      GO TO 210
190   W2(1)=0.
      W2(2)=1.
      GO TO 210
200   I2CC=I2C+NT
      I2C=-I2C
      W2(1)=-S(I2C)
      W2(2)=S(I2CC)
210   I3=I+I2
      I3C=NT-I3
      IF (I3C) 240,230,220
220   W3(1)=S(I3C)
      W3(2)=S(I3)
```

```
      GO TO 280
230   W3(1)=0.
      W3(2)=1.
      GO TO 280
240   I3CC=I3C+NT
      IF (I3CC) 270,260,250
250   I3C=-I3C
      W3(1)=-S(I3C)
      W3(2)=S(I3CC)
      GO TO 280
260   W3(1)=-1.
      W3(2)=0.
      GO TO 280
270   I3CCC=NT+I3CC
      I3CC=-I3CC
      W3(1)=-S(I3CCC)
      W3(2)=-S(I3CC)
280   ILAST=IL+JJ
      DO 290 I=JJ,ILAST,IDIF
      KLAST=KL+I
      DO 290 K=I,KLAST,2
      K1=K+KBIT
      K2=K1+KBIT
      K3=K2+KBIT
      R=A(K2)*W2(1)-A(K2+1)*W2(2)
      T=A(K2)*W2(2)+A(K2+1)*W2(1)
      A(K2)=A(K)-R
      A(K)=A(K)+R
      A(K2+1)=A(K+1)-T
      A(K+1)=A(K+1)+T
      R=A(K3)*W3(1)-A(K3+1)*W3(2)
      T=A(K3)*W3(2)+A(K3+1)*W3(1)
      AWR=A(K1)*W(1)-A(K1+1)*W(2)
      AWI=A(K1)*W(2)+A(K1+1)*W(1)
      A(K3)=AWR-R
      A(K3+1)=AWI-T
      A(K1)=AWR+R
      A(K1+1)=AWI+T
      T=A(K1)
      A(K1)=A(K)-T
      A(K)=A(K)+T
      T=A(K1+1)
      A(K1+1)=A(K+1)-T
      A(K+1)=A(K+1)+T
      R=-A(K3+1)
      T=A(K3)
      A(K3)=A(K2)-R
      A(K2)=A(K2)+R
      A(K3+1)=A(K2+1)-T
290   A(K2+1)=A(K2+1)+T
300   JJ=JJDIF+JJ
310   JLAST=4*JLAST+3
320   CONTINUE
330   CONTINUE
      NTSQ=NT*NT
      M3MT=M3-MT
      IF (M3MT) 350,340,340
```

```
340   IGO3=1
      N3VNT=N3/NT
      MINN3=NT
      GO TO 360
350   IGO3=2
      N3VNT=1
      NTVN3=NT/N3
      MINN3=N3
360   JJD3=NTSQ/N3
      M2MT=M2-MT
      IF (M2MT) 380,370,370
370   IGO2=1
      N2VNT=N2/NT
      MINN2=NT
      GO TO 390
380   IGO2=2
      N2VNT=1
      NTVN2=NT/N2
      MINN2=N2
390   JJD2=NTSQ/N2
      M1MT=M1-MT
      IF (M1MT) 410,400,400
400   IGO1=1
      N1VNT=N1/NT
      MINN1=NT
      GO TO 420
410   IGO1=2
      N1VNT=1
      NTVN1=NT/N1
      MINN1=N1
420   JJD1=NTSQ/N1
      JJ3=1
      J=1
      DO 570 JPP3=1,N3VNT
      IPP3=INV(JJ3)
      DO 560 JP3=1,MINN3
      GO TO (430,440), IGO3
430   IP3=INV(JP3)*N3VNT
      GO TO 450
440   IP3=INV(JP3)/NTVN3
450   I3=(IPP3+IP3)*N2
      JJ2=1
      DO 560 JPP2=1,N2VNT
      IPP2=INV(JJ2)+I3
      DO 550 JP2=1,MINN2
      GO TO (460,470), IGO2
460   IP2=INV(JP2)*N2VNT
      GO TO 480
470   IP2=INV(JP2)/NTVN2
480   I2=(IPP2+IP2)*N1
      JJ1=1
      DO 550 JPP1=1,N1VNT
      IPP1=INV(JJ1)+I2
      DO 540 JP1=1,MINN1
      GO TO (490,500), IGO1
490   IP1=INV(JP1)*N1VNT
      GO TO 510
```

```
500    IP1=INV(JP1)/NTVN1
510    I=2*(IPP1+IP1)+1
       IF (J-I) 520,530,530
520    T=A(I)
       A(I)=A(J)
       A(J)=T
       T=A(I+1)
       A(I+1)=A(J+1)
       A(J+1)=T
530    CONTINUE
540    J=J+2
550    JJ1=JJ1+JJD1
560    JJ2=JJ2+JJD2
570    JJ3=JJ3+JJD3
       IF (IFSET) 580,600,600
580    DO 590 I=1,NX
590    A(2*I)=-A(2*I)
600    RETURN
       END
       SUBROUTINE RFFT (A,M,INV,S,IFERR,IFSET)
       IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C      REAL*8 A,S
       DIMENSION A(1), L(3), INV(1), S(1)
C      IFSET=1
       L(1)=M
       L(2)=0
       L(3)=0
       NTOT=2**M
       NTOT2=2*NTOT
       FN=NTOT
       DO 10 I=2,NTOT2,2
10     A(I)=-A(I)
       DO 20 I=1,NTOT2
20     A(I)=A(I)/FN
       CALL FFT (A,L,INV,S,IFSET,IFERR)
C
C      MOVE LAST HALF OF A(J)S DOWN ONE SLOT AND ADD A(N) AT BOTTOM TO
C      GIVE ARRAY FOR A1PRIME AND A2PRIME CALCULATION
C
       DO 30 I=1,NTOT,2
       J0=NTOT2+2-I
       A(J0)=A(J0-2)
30     A(J0+1)=A(J0-1)
       A(NTOT2+3)=A(1)
       A(NTOT2+4)=A(2)
C
C      CALCULATE A1PRIMES AND STORE IN FIRST N SLOTS
C      CALCULATE A2PRIMES AND STORE IN SECOND N SLOTS IN REVERSE ORDER
       K0=NTOT+1
       DO 40 I=1,K0,2
       K1=NTOT2-I+4
       AP1RE=.5*(A(I)+A(K1))
       AP2RE=-.5*(A(I+1)+A(K1+1))
       AP1IM=.5*(-A(I+1)+A(K1+1))
       AP2IM=-.5*(A(I)-A(K1))
       A(I)=AP1RE
       A(I+1)=AP1IM
```

```
      A(K1)=AP2RE
40    A(K1+1)=AP2IM
      NTO=NTOT/2
      NT=NTO+1
      DEL=3.1415927/FLOAT(NTOT)
      SS=SIN(DEL)
      SC=COS(DEL)
      SI=0.0
      CO=1.0
C
C     COMPUTE C(J)S FOR J=0 THRU J=N
      DO 50 I=1,NT
      K6=NTOT2-2*I+5
      AP2RE=A(K6)*CO+A(K6+1)*SI
      AP2IM=-A(K6)*SI+A(K6+1)*CO
      CIRE=.5*(A(2*I-1)+AP2RE)
      CIIM=.5*(A(2*I)+AP2IM)
      CNIRE=.5*(A(2*I-1)-AP2RE)
      CNIIM=.5*(A(2*I)-AP2IM)
      A(2*I-1)=CIRE
      A(2*I)=CIIM
      A(K6)=CNIRE
      A(K6+1)=-CNIIM
      SIS=SI
      SI=SI*SC+CO*SS
50    CO=CO*SC-SIS*SS
C
C     SHIFT C(J)S FOR J=N/2+1 TO J=N UP ONE SLOT
      DO 60 I=1,NTOT,2
      K8=NTOT+4+I
      A(K8-2)=A(K8)
60    A(K8-1)=A(K8+1)
      DO 70 I=3,NTOT2,2
      A(I)=2.*A(I)
70    A(I+1)= 2.*A(I+1)
      RETURN
      END
      SUBROUTINE RFSN (A,M,INV,S,IFERR,IFSET)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C     REAL*8 A,S
      DIMENSION A(1),L(3),INV(1),S(1)
      L(1)=M
      L(2)=0
      L(3)=0
      NTOT=2**M
C     IFSET=-1
      NTOT2=NTOT+NTOT
      NN=NTOT2+2
      A(NN+2)=A(NN)
      A(NN+1)=A(NN-1)
      FN=NTOT
      NTOT3=NTOT2+4
      DO 70 I=3,NTOT2,2
      A(I)=0.5* A(I)
   70 A(I+1)= .5*A(I+1)
      DO 60 I=1,NTOT,2
      K8=NTOT2+2-I
```

```
      A(K8)= A(K8-2)
   60 A(K8+1)=A(K8-1)
      NTO=NTOT/ 2
      NT=NTO+1
      DEL=3.14159265/FN
      SS= SIN(DEL)
      SC= COS(DEL)
      SI=0.
      CO =1.0
      DO 50 I=1,NT
      K6=NTOT2-2*I+5
      CIRE= A(2*I-1) + A(K6)
      CIIM=A(2*I)-A(K6+1)
      CNIRE=(-SI*(A(2*I)+A(K6+1))+CO*(A(2*I-1)-A(K6)))
      IF(SI)62,61,62
   62 CNIIM=(A(2*I-1)-A(K6)-CO*CNIRE)/SI
      GO TO 63
   61 CNIIM=0.
   63 A(2*I-1)=CIRE
      A(2*I)=CIIM
      A(K6)=CNIRE
      A(K6+1)=CNIIM
      SIS=SI
      SI=SI*SC+CO*SS
   50 CO=CO*SC-SIS*SS
      KO=NTOT+1
      DO 40 I=1,KO,2
      K1=NTOT2-I+4
      AP1RE=A(I)-A(K1+1)
      AP2RE=-(A(I+1)+A(K1))
      AP1IM=A(I)+A(K1+1)
      AP2IM=A(I+1)-A(K1)
      A(I)=AP1RE
      A(I+1)=AP2RE
      A(K1)=AP1IM
   40 A(K1+1)=AP2IM
      NTOP=NTOT2+2
      NT00=NTOT+1
      A(1)=A(NTOT2+3)
      A(2)=A(NTOT2+4)
   21 DO 52 I=NT00,NTOP,2
      A(I)=A(I+2)
   52 A(I+1)=A(I+3)
      CALL  FFT(A,L,INV,S,IFSET,IFERR)
      DO 20 I=1,NTOT2
   20 A(I)=A(I)*FN
      DO 10 I=2,NTOT2,2
   10 A(I)=-A(I)
      RETURN
      END
```

298