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Guide for Mechanistic-Empirical Design
OF NEW AND REHABILITATED PAVEMENT STRUCTURES

FINAL DOCUMENT

APPENDIX II-1:
CALIBRATION OF FATIGUE CRACKING MODELS FOR FLEXIBLE PAVEMENTS

NCHRP

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Research into the subject area covered in this Appendix was conducted at ASU. The authors of this Appendix are Dr. M.W. Witczak and Mr. M. M. El-Basyouny.

Foreword

This appendix is the first in a series of three volumes on Calibration of Fatigue Cracking Models for Flexible Pavements. This volume concentrates on the selection, development, of calibration and validation aspects of the fatigue cracking models selected for the Design Guide. Both types of fatigue cracking (bottom up and top down) are discussed separately in the following sections. The fatigue cracking discussion will consist of: an overview of two widely used fatigue models evaluated for inclusion in the Design Guide. For each model evaluated, fatigue-cracking comparisons of data collected from the LTPP database will be discussed. Finally the calibration of the final fatigue cracking model and the reliability of the model selected are explained in detail.

The other volumes are:

Appendix II-2:	Sensitivity Analysis for Asphalt Concrete Fatigue Alligator Cracking
Appendix II-3:	Sensitivity Analysis for Asphalt Concrete Fatigue Longitudinal Surface Cracking

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Appendix II-1

Calibration of Fatigue Cracking Models for Flexible Pavements

Annex A – Calibration of Fatigue Cracking Models For Flexible Pavements

Introduction

Load-associated fatigue cracking is one of the major distress types occurring in flexible pavement systems. The action of repeated traffic loads induces tensile and shear stresses in all chemically stabilized layers, which eventually lead to a loss in the structural integrity of the stabilized layer. Repeated load or fatigue cracks initiate at points where the critical tensile strains and stresses occur. The location of the critical strain/stress is dependent upon several factors. The most important is the stiffness of the layer and the load configuration. In addition, it should be realized that the maximum tensile strain developed within the pavement system might not be the most critical or damaging value. This is because the critical strain is a function of the stiffness of the mix. Since the stiffness of an asphalt mix in a layered pavement system varies with depth, these changes will eventually effect the location of the critical strain that causes fatigue damage. Once the damage initiates at the critical location, the continued action of traffic eventually causes these cracks to propagate through the entire bound layer.

Propagation of the cracks throughout the entire layer thickness will eventually allow water to seep into the lower unbound layers, weakening the pavement structure and reducing the overall performance. This will result in increased roughness of the pavement system, causing a decrease in pavement serviceability. This phenomenon of crack initiation and then propagation through the entire layer occurs not only in the surface layer but also in all the stabilized layers underneath. Cracking in an underlying layer, such as a cement stabilized subbase, also reduces the overall structural capacity of the layer (and pavement) and may induce reflective cracking in the upper layers.

Over the last 3 to 4 decades of pavement technology, it has been common to assume that fatigue cracking normally initiates at the bottom of the asphalt layer and propagates to the surface (bottom-up cracking). This is due to the bending action of the pavement layer that results in flexural stresses to develop at the bottom of the bound layer. However, numerous recent worldwide studies (1, 2, 3, 4) have also clearly demonstrated that fatigue cracking may also be initiated from the top and propagate down (top-down cracking). This type of fatigue is not as well defined from a mechanistic viewpoint as the more classical "bottom-up" fatigue. However, it is a reasonable engineering assumption, with the current state of knowledge, that this distress may be due to critical tensile and/or shear stresses developed at the pavement surface and, perhaps, caused by extremely large contact pressures at the tire edge-pavement interface; coupled with highly aged (stiff) thin surface layer that have become oxidized. In this initial mechanistic attempt to model top-down cracking in the Design Guide; the failure mechanism for this distress is hypothesized to be a result of tensile surface strains leading to fatigue cracking at the pavement surface.

This chapter concentrates on the selection, development, of calibration and validation aspects of the fatigue cracking models selected for the Design Guide. Both types of fatigue cracking (bottom up and top down) are discussed separately in the following sections. The fatigue cracking discussion will consist of: an overview of two widely used fatigue models evaluated for inclusion in the Design Guide. For each model evaluated, fatigue-cracking comparisons of data collected from the LTPP database will be discussed. Finally the calibration of the final fatigue cracking model and the reliability of the model selected are explained in detail.

Asphalt Mixture Fatigue Cracking Models

Fatigue cracking prediction is normally based on the cumulative damage concept given by Miner's (5). The damage is calculated as the ratio of the predicted number of traffic repetitions to the allowable number of load repetitions (to some failure level) as shown in equation 1. Theoretically, fatigue cracking should occur at an accumulated damage value of 1. If a normal distribution is assumed for the damage ratio calculated, the percentage of area cracked can be computed and checked with field performance.

$$D = \sum_{i=1}^{T} \frac{n_i}{N_i} \tag{1}$$

where:

D = damage.
T = total number of periods.
n_i = actual traffic for period i.
N_i = allowable failure repetitions under conditions prevailing in period i.

The fatigue life of an asphalt concrete mixture is influenced by many factors. Several key mix properties such as asphalt type, asphalt content and air-void content are well known to influence fatigue. Other factors such as temperature, frequency, and rest periods of the applied load also are known to influence fatigue life. Other material properties may also affect the fatigue life. It is obvious that mix properties need to be carefully balanced to optimize fatigue cracking of any mixtures.

In the literature, the most commonly used model form to predict the number of load repetitions to fatigue cracking is a function of the tensile strain and mix stiffness (modulus). The critical locations of the tensile strains may either be at the surface (result in top-down cracking) or at the bottom of the asphaltic layer (result in bottom-up cracking).

The general mathematical form of the number of load repetitions used in the literature is shown in equation 2. The form of the model is a function of the tensile strains at a given location and modulus of the asphalt layer.

$$N_f = Ck_1\left(\frac{1}{\varepsilon_t}\right)^{k_2}\left(\frac{1}{E}\right)^{k_3} \qquad (2)$$

where:

N_f	=	Number of repetitions to fatigue cracking.
ε_t	=	*Tensile* strain at the critical location.
E	=	*Stiffness* of the material.
k_1, k_2, k_3	=	*Laboratory* regression coefficients.
C	=	Laboratory to field adjustment factor.

The most commonly used fatigue cracking models are those developed by Shell Oil (6) and the Asphalt Institute (MS-1) (7). The overall general form of each model is the same mathematical model form shown above. However, the difference is in the laboratory regression coefficients in the equation and the laboratory to field adjustment factor. In the following section these two models will be discussed, showing the difference between the two models and the effect of the laboratory testing procedure on the models.

It has to be noted that the fatigue-cracking model, which calculates the number of cycles to failure is only expressing the stage of fatigue cracking described as the crack initiation stage. The second stage, or vertical crack propagation stage, is accounted for in these models by using the field adjustment factor. Other models in the literature use two different equations to express each stage of the fatigue cracking. For example, Lytton et al. (8) used fracture mechanics based upon the Paris law to model the crack propagation stage in his development of the theoretical Superpave Model. Finally, another (third) stage of fatigue fracture is associated with the growth in longitudinal area, in which fatigue cracking occurs. In general, true field fatigue failure is generally associated with a percentage of fatigue cracking along the roadway.

Constant Stress Vs Constant Strain Analysis

In the laboratory, two types of controlled loading are generally applied for fatigue characterization: constant stress and constant strain. In constant stress (load) testing, the applied stress during the fatigue testing remains constant. As the repetitive load causes damage in the test specimen, the stiffness of the mix is decreased due to the micro cracking observed. This, in turn, leads to an increase in tensile strain with load repetitions. In the constant strain test, the strain remains constant with the number of repetitions. Because of specimen damage due to the repetitive loading; the stress must be reduced to obtain the same strain. This leads to a reduced stiffness as a function of repetitions. The constant stress and constant strain phenomena are shown in Figure 1.

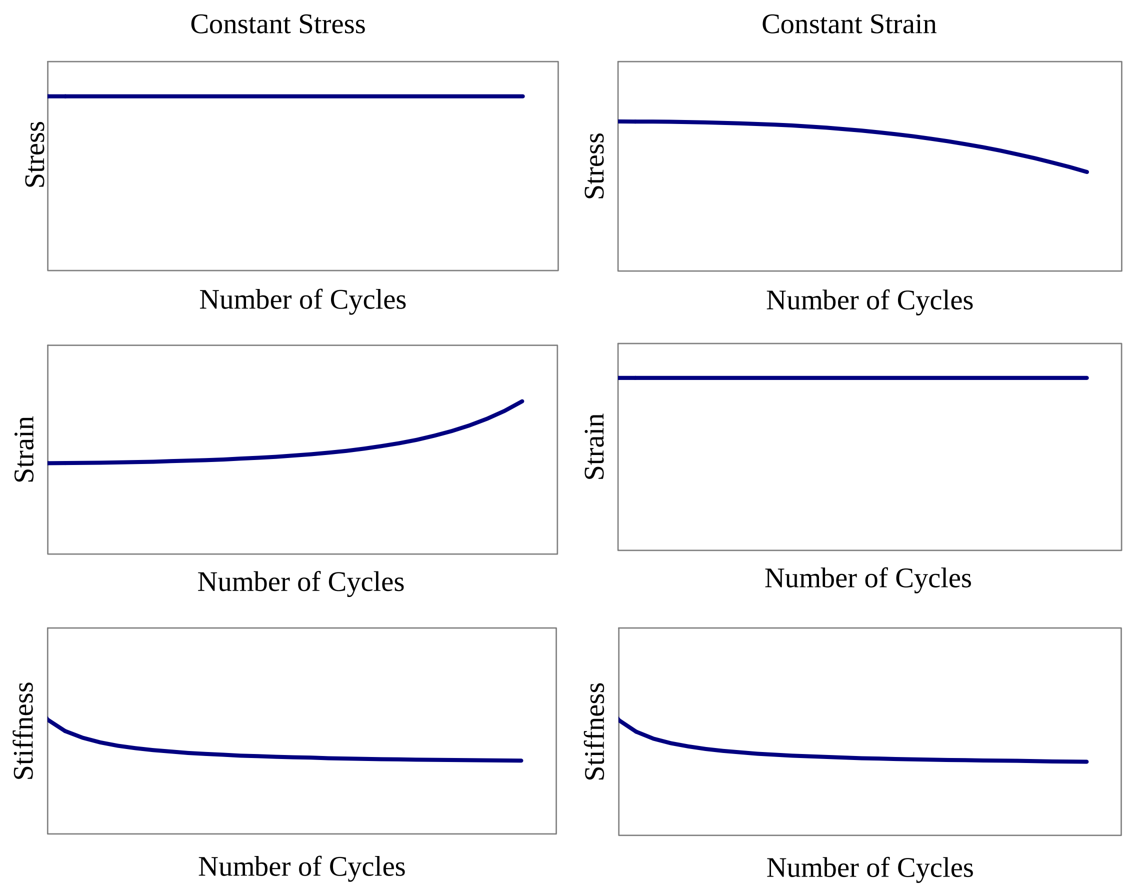


Figure 1 Constant Stress and Constant Strain Phenomena

The constant stress type of loading is generally considered applicable to thick asphalt pavement layers usually more than 8 inches. In this type of structure, the thick asphalt layer is the main load-carrying component and the strain increases, as the material gets weaker under repeated loading. However, with the reduction in the stiffness, because of the thickness, changes in the stress are not significant and this fact leads to a constant stress situation.

The constant strain type of loading is considered more applicable to thin asphalt pavement layers usually less than 2 inches. The pavement layer is not the main load-carrying component. The strain in the asphalt layer is governed by the underlying layers and is not greatly affected by the change in the asphalt layer stiffness. This situation is conceptually more related to the category of constant strain. However, for intermediate thicknesses, fatigue life is generally governed by a situation that is a combination of constant stress and constant strain.

Shell Oil Model

Because of the known impact between stress states and damage mechanism for different thicknesses of asphalt layers, the Shell Oil Co. has developed fatigue damage prediction equations for the two major forms of laboratory fatigue testing. The equations developed are summarized below (6):

Constant Strain

$$N_f = A_f[0.17PI - 0.0085PI(V_b) + 0.0454V_b - 0.112]^5 \varepsilon_t^{-5} E^{-1.8} \tag{3a}$$

Constant Stress

$$N_f = A_f[0.0252PI - 0.00126PI(V_b) + 0.00673V_b - 0.0167]^5 \varepsilon_t^{-5} E^{-1.4} \tag{3b}$$

In the above equation PI is the penetration index as is defined by the following equations:

$$PI = \frac{20 - 500A}{1 + 50A} \tag{4a}$$

"A" is the temperature susceptibility, which is the slope of the logarithm of penetration versus temperature plot. Mathematically, this is expressed as:

$$A = \frac{\log(pen\ at\ T_1) - \log(pen\ at\ T_2)}{T_1 - T_2} \tag{4b}$$

T_1 and T_2 are temperatures in centigrade (^{o}C), at which penetrations are measured. In addition to the above equation, *A* can also be obtained from the following equation.

$$A = \frac{\log(pen\ at\ T) - \log 800}{T - T_{R\&B}} \tag{4c}$$

$T_{R\&B}$ is the softening point or the Ring & Ball temperature as specified by AASHTO (T53-84). Softening point temperature is the reference temperature (equi-viscous) at which all bitumens have the same consistency (viscosity or penetration). Tests have shown that at the $T_{R\&B}$ temperature, the penetration of all bitumens is near 800. Replacing T_2 in equation 4b by $T_{R\&B}$ and pen at T_2 by 800 results in equation 4c.

In developing an implementation scheme for equation 3, Witczak hypothesized that the constant strain case was applicable for asphalt layer thickness of 2-inch or less and that the constant stress case was applicable for asphalt layer thickness of 8-inch or more. No relationship was available for intermediate thicknesses (thickness value between 2 and 8 inches), which are the most common asphaltic thickness values used in the majority of flexible pavement construction.

In order to overcome this problem, a numerical transition approach was developed by M. W. Witczak and M. W. Mirza (9) during the NCHRP 1-37A research to come-up with a generalized fatigue equation applicable to a broad range of thickness values. The methodology developed is based upon the constant stress and constant strain equations presented earlier (equation 3). Comparing equations 3a and 3b, it is apparent that the K_1 factor represents the volumetric and the binder characteristics of the mix. Further examination of equations 4a and 4b reveals that for all practical purposes; each parameter coefficient ratio within the K_1 term is:

$$\alpha = \frac{Const.\ Strain\ a_i}{Const.\ Stress\ a_i} \tag{5a}$$

$$\alpha_1 = \frac{0.17PI}{0.0252PI} = 6.746 \tag{5b}$$

$$\alpha_2 = \frac{0.0085PI(V_b)}{0.00126PI(V_b)} = 6.746 \tag{5c}$$

$$\alpha_3 = \frac{0.0454V_b}{0.00673V_b} = 6.746 \tag{5d}$$

$$\alpha_4 = \frac{0.112}{0.0167} = 6.707 \tag{5e}$$

Thus, the average α for the four factors is 6.74. That is, the K_1 values in the two fatigue equations differ by a factor of $\alpha^5 = 6.74^5 = 13{,}909$. Another difference observed between the constant stress and constant strain equations is the power of the modulus term (E). A value of $k_3 = 1.8$ occurs for the constant strain ($h_{ac} \leq 2$ inch) condition, while 1.4 is present for constant stress ($h_{ac} \geq 8$ inch). Based upon these findings, a generalized (modified) Shell Oil based fatigue equation for each mode of loading is given by:

Constant Strain: $$N_{f\varepsilon} = 13909 A_f K_{1\alpha}\left(\frac{1}{\varepsilon_t}\right)^5 E^{-1.8} \tag{6a}$$

Constant Stress: $$N_{f\sigma} = A_f K_{1\alpha}\left(\frac{1}{\varepsilon_t}\right)^5 E^{-1.4} \tag{6b}$$

It should be noted that the K_1 value in the above equations is replaced by the $K_{1\alpha}$ value. The $K_{1\alpha}$ represents the K_1 value for the constant stress situation. Taking the ratio of these two equations results in the following relationship.

$$F = \frac{N_{f\varepsilon}}{N_{f\sigma}} = 13909 * E^{-0.4} \tag{7a}$$

That is:

$$N_{f\varepsilon} = F * N_{f\sigma} \tag{7b}$$

In the above equation F represents the ratio between the constant strain and constant stress and is a function of the modulus (E) of asphalt layer. Estimated values of F as a function of the modulus of the mix are given in Table 1. It is to be noted that the value of F is always one for the constant stress situation. That is, for a modulus value of 1,000,000 psi, F-value for constant strain situation is 55.3. This means that under the constant strain situation, the fatigue life of an asphalt mix, at a mix stiffness of 1,000,000 psi, is 55.3 times that predicted under constant stress conditions.

Table 1 only provides F-values for the two extreme conditions, constant strain (thickness <= 2 inch) and constant stress situation (thickness => 8 inch). In order to have a continuous function between constant strain and stress conditions, it was assumed that a sigmoidal relationship, between the two F conditions and all intermediate thickness (2 inches to 8 inches), would be applicable. Thus, a sigmoidal function of F" was defined

Table 1 Calculated F Values for Constant Strain and Constant Stress Situation

Modulus (E), psi	Constant Strain ($h_{ac} \le 2$ inch)	Constant Stress ($h_{ac} \ge 8$ inch)
50,000	183.4	1.0
100,000	139.0	1.0
500,000	73.0	1.0
1,000,00	55.3	1.0
5,000,00	29.0	1.0

(developed) to be given by:

$$F'' = 1 + \frac{F}{1 + \exp^{(1.354 h_{ac} - 5.408)}} \quad (8)$$

Equation 8 provides F''-values as a function of the F-value (Equation 7a) and the thickness, providing a continuous fatigue relationship. This function is shown in Equation 9.

$$N_f = A_f \; F'' K_{1\sigma} \left(\frac{1}{\varepsilon_t} \right)^5 E^{-1.4} \quad (9)$$

The sigmoidal relationship shown in the above equation is also graphically shown in Figure 2. The F''-values shown are noted to be functions of the stiffness of the mix. It is important to note that the F''-value decreases with increasing modulus. This implies that the difference in fatigue life between constant strain and constant stress decreases as the stiffness increases. The overall generalized equation developed based upon the above analysis is presented in Table 2

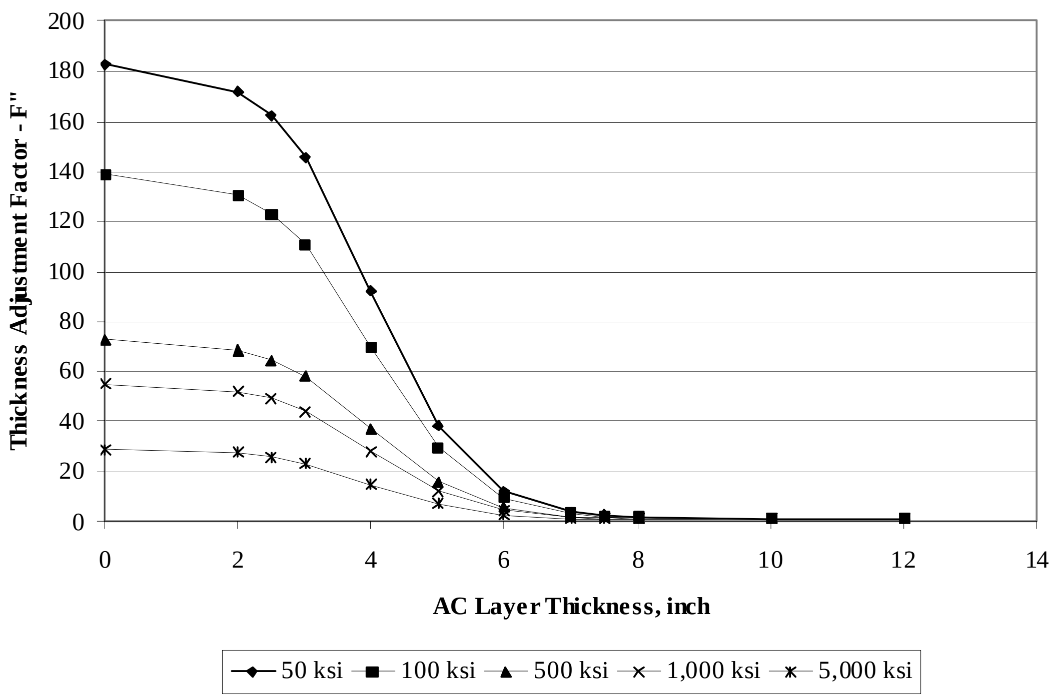


Figure 2 Sigmoidal Fit to Fatigue Equation Parameters

Table 2 Generalized Shell Oil Fatigue Equations

$$N_f = A_f \left(1 + \frac{13909E^{-0.4} - 1}{1 + \exp^{(1.354h_{ac} - 5.408)}}\right)(0.0252PI - 0.00126PI(V_b) + 0.00673V_b - 0.0167)^5 \left(\frac{1}{\varepsilon_t}\right)^5 \left(\frac{1}{E^*}\right)^{-1.4}$$

where

$$F'' = 1 + \frac{13909E^{-0.4} - 1}{1 + \exp^{(1.354h_{ac} - 5.408)}}$$

$K_{1\alpha}$ $= [0.0252PI - 0.00126PI(V_b) + 0.00673V_b - 0.0167]^5$

A_f = laboratory to field adjustment factor (default = 1.0)

Asphalt Institute (MS-1) Model

The Asphalt Institute's (7) fatigue equation is based upon modifications to constant stress laboratory fatigue criteria. Because the approach developed by Witczak and Shook (10) was applicable to thicker full-depth asphalt pavements, use of any type of controlled strain results were not incorporated. The number of load repetitions to failure is expressed in the same mathematical form as the Shell Oil model and it is given by:

$$N_f = 0.00432C\left(\frac{1}{\varepsilon_t}\right)^{3.291}\left(\frac{1}{E}\right)^{0.854}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right) \tag{10}$$

where:

V_b = effective binder content (%).

V_a = air voids (%).

This equation (model), developed by Witczak et al (7) for the Ninth Edition of MS-1, utilized the basic fatigue relationship developed under NCHRP 1-10 by Fred Finn et al. (11) and modified by Witczak to incorporate mixture volumetric adjustments developed by Monismith et al.

The Asphalt Institute Ninth Edition of the MS-1 design manual (7) used a field calibration factor of 18.4 to adjust for the effect of the laboratory to field differences. This correction factor was developed for a 20% level cracking in the wheel path and was that recommended by Finn in his classic NCHRP 1-10 study (11).

Comparing the Shell Oil model to the MS-1 model will lead to the conclusion that both models are exactly the same form. However, the coefficients are less for the MS-1 model compared to the Shell Oil. This would be reasonable to accept because the Shell Oil relationships are based upon laboratory testing while the MS-1 equation (derived from NCHRP 1-10) was heavily based upon actual field calibration studies.

While there are many other available fatigue models, which are found in the literature, the dissertation (and implementation into the Design Guide) focused only on the Shell Oil and the MS-1 models. This was accomplished because it was the opinion of the NCHRP 1-37A team, that these two models represented the most powerful and accurate state of the art fatigue models for potential inclusion into the final Design guide.

Calibration of Fatigue Cracking Models

The asphalt concrete mix fatigue-cracking models (both bottom-up cracking and top-down cracking) were calibrated following the process noted below:

1. Calibration (performance) data was collected from the LTPP database for each field section.
2. Simulation (predictive) runs were done using the 2002 Design Guide software and using a different set of calibration coefficients in the number of load repetition model.
3. The predicted damage from each calibration coefficient combination was compared to the measured cracking observed in the field. The coefficient combination with the least scatter of the data and the correct trends was selected.
4. The predicted damage was correlated to the measured cracking in the field by minimizing the square of the errors.

The calibration data collection was done at the same time for both types of fatigue cracking as the same sections were used for both bottom-up and top-down cracking calibration. In the following sections each step of the above listed calibration steps is discussed in details. The calibration data will be presented in a general section for both fatigue- cracking types, and then each fatigue cracking model calibration will be discussed separately.

Calibration Data

The main source used to obtain performance data for the calibration of the fatigue cracking was the LTPP database. Data were mainly obtained from the General Pavement Sites (GPS) and the Special Pavement Sites (SPS) (12). Appendix EE includes a detailed listing of the sections and the section data used in the calibration process, as well as any assumptions made for some of these sections to replace missing data. In a limited number of cases some parameters were not found. These values were assumed using a default value based on experience and the literature review. Appendix EE1 includes the data for the new pavement sections (13), while Appendix EE-2 includes the data for the rehabilitation pavement sections (14). It has to be noted that the rehabilitation data is included in the dissertation. However, the calibration of the rehabilitation sections is not an inherent part of this dissertation. The rehabilitation section calibration, however, is included as a part of the NCHRP 1-37A final reports and publications.

Two requirements for calibrating the performance prediction models are to ensure that all major factors that influence the development of pavement distress are included and to ensure that the selected test pavements span the expected range of each factor. The approach used in the plan for model calibration was to select the desired number of field sections as well as desirable attribute values (ranges) of key factors; following generally accepted experimental statistical concepts. The approach emphasizes the recognition of key parameters for the factors of interest, selection of the appropriate number of levels for a factor, and the selection of the number of replicates within each cell of the experiment design. These experiments were designed to:

- Statistically test the hypothesis of distress failure mechanism.
- Determine whether there is any bias in the predictions.
- Establish the cause of any bias.
- Determine the calibration function.

Age (or time) and the independent variables (material properties) of the transfer functions were treated as continuous variables for the load-related distress. Traffic was also treated as a continuous variable for the load-related distress. Only Traffic level 1, involving the actual traffic axle load spectra, was used in the calibration.

The primary purpose of the fatigue-cracking model is to predict the amount of load-related cracking with time and/or number of axle load applications. Four key factors were considered in the experiment design for model calibration. These are listed and noted below, along with other considerations that were used in the site selection process.

- The temperature (environment) is a critical parameter for fatigue cracking since it influences the tensile strains and stresses present in the pavement. Temperature is included as a key factor in the experiment to determine whether different climatic conditions result in any biases of the predictions.
- A second critical factor is the total HMA thickness. The total HMA layer thickness not only influences strain and stress magnitude, but is directly linked to the location where fatigue cracks initiate as well as under the specific mode of loading (constant stress or strain) under which fracture occurs. Thus, total HMA thickness is considered a key factor in the experiment.
- Pavement type and rehabilitation strategy are additional factors of the experiment for checking the key failure hypothesis and to determine whether there is any bias for the different pavement structures or calculation methodologies.
- The resilient modulus of the subgrade soil is an important factor related to the occurrence of fatigue cracks. However, most of the experimental designs in the LTPP program include the type of subgrade soil. For the fatigue calibration experiment, subgrade soil type is included as a secondary factor.
- Mix stiffness (dynamic modulus) is an important parameter for fatigue cracking in that it influences the traditional tensile strain-fatigue cycle distress curve. The dynamic modulus is dependent on (or is a function of) temperature and age, among other mixture properties, and is considered a co-variant parameter in the experiment.
- It is intuitively obvious that the model must represent a range of fatigue cracking that covers the normal range found along roadways. If an

adequate range of cracking extent or magnitude is not included, the accuracy of the model over a wide range will be questionable. Thus, the distress magnitude is the fourth important factor considered in the calibration process. Field sections with varying levels of fatigue cracks were included in the experimental plan to cover the range of conditions. However, due to the availability of time-series distress data for each test section, the range in fatigue cracking was not included as a key factor in the experiment. Fatigue cracking magnitude was used in selecting the test sections for the individual cells.

The field sections were selected randomly to ensure that a well-balanced matrix of salient pavement parameters and fatigue cracking was present in the experiment. The models were evaluated based on bias, precision, and accuracy, as defined below,

- Bias – An effect that deprives predictions of simulating “real world” observations by systematically distorting it, as distinct from a random error that may distort on any one occasion but balances out on the average.
- Precision – The ability of a model to give repeated estimates that are very close together.
- Accuracy – The closeness of predictions to the “true” or “actual” value. The concept of accuracy encompasses both precision and bias.

Site Selection Criteria and Considerations

The following lists and briefly defines the criteria that were considered in selecting and prioritizing sites for use in the calibration and validation of the Design Guide distress prediction models for flexible pavements.

- **Consistency of Measurements –** It is imperative that a consistent definition and measurement of the surface distresses and other data be used and maintained throughout the calibration and validation process. All data used to establish the inputs for the models (including, material test results, climatic data, and traffic data) and performance monitoring, are collected or measured in accordance with the FHWA LTPP publication Data Collection Guide For Long Term Pavement Performance (15) or with an equivalent method.
- **Time-Series Distress Data –** Projects or test sections that have three or more distress surveys or observations within their analysis life were given a high priority in the site selection process.
- **Materials Characterization and Testing** – Materials tests or properties were required for each input level. However, material testing (level 1 type) is outside the scope of this research work. Thus, test sections for which the material properties have already been measured are required for

use to calibrate the distress prediction models. The material properties of the pavement layers must be measured with the same test protocols to ensure that the results are compatible between different projects and test sections.

- **Number of Layers –** The test sections with the fewest number of structural layers and materials (e.g., one or two asphalt concrete layers, one unbound base layer, and one subbase layer) were given a higher priority to reduce the data collection requirements, as well as the complexity of the analysis.
- **Traffic –**The recommended traffic data collection frequency is one week per quarter year, or during periods of peak truck traffic. First priority in the selection of field sections for the calibration experiments was given to those in the LTPP inventory equipped with continuous WIM. Unfortunately, many LTPP test sections do not have continuous WIM data, even for a limited number of years. Thus, a second priority in the selection of field sections was given to those test sections with seasonal WIM monitoring with the greatest frequency of sampling and continuous AVC sampling for multiple years.
- **Rehabilitation and New Construction –** The computation methodology (incremental damage accumulation) to simulate a distress mechanism for both new construction (original pavement surfaces) and rehabilitation (overlays) will be different for some distresses. As a result, test sections with and without overlays were needed for the calibration and validation experiments.
- **Maximum Use of Test Sections Between Model Studies –** Coordination of field activities between projects can substantially reduce the number of test sections that will be required if each project were conducted independently from the others. Those projects or test sections that are planned for use on other research projects were given a higher priority for use in the calibration-validation process of the Design Guide distress prediction models.
- **Non-Conventional Mixtures –** Those test sections that include non-conventional mixtures or layers were given a higher priority for the site selection process. These non-conventional mixtures include: SMA, modified HMA, and open-graded drainage layers. However, open-graded drainage layers were the only non-conventional material that was used in the GPS and SPS-1 and 5 experiments. Thus, it can be stated that the calibration process was principally based upon conventional dense graded type of asphalt mixtures.
- **Experimental Optimization/Efficiency –** The test sections for the calibration and validation studies came from the SPS and GPS sites included in the LTPP program. Fewer number of sections was used because of the cost and time required for data collection and review.

Those test sections that were used for multiple factorials were given a higher priority for the site selection process.

Identification of Test Sections

The first activity of the site selection process was to categorize all test sections applicable for both the calibration experiments based on the data requirements. The following LTPP studies meet the general criteria listed above:

- GPS,
- SPS-1, Structural Factors for Flexible Pavements.
- SPS-5, Rehabilitation of Asphalt Concrete Pavements.

In summary, these projects include varying climates, traffic levels, subgrade soils, and pavement structural cross sections. The specific sites used in the calibration process are shown in Figure 3 and Figure 4. There were 136 LTPP test sections (94 new sections and 42 overlay sections) used for the calibration. As previously noted, the specific details for each test section are summarized in Appendix EE.

These test sections cover a diverse range of site features. All data required for executing the models, including the model inputs and measures of fatigue distress, were extracted, reviewed for accuracy and completeness, and incorporated into a project database. These data elements included performance observations (measurements of distress), material properties, traffic and climatic characteristics, pavement cross-section, foundation and many others.

The LTPP database provided the fatigue cracking data according to its severity level (low, medium and high severity) for each LTPP section. The LTPP sections had a length of 500 feet. In this research project, it was decided, by the NCHRP Panel over viewing the study, that the summation of the three fatigue cracking severity values would be added arithmetically and used as the total fatigue cracking, without using any weights for each severity category.

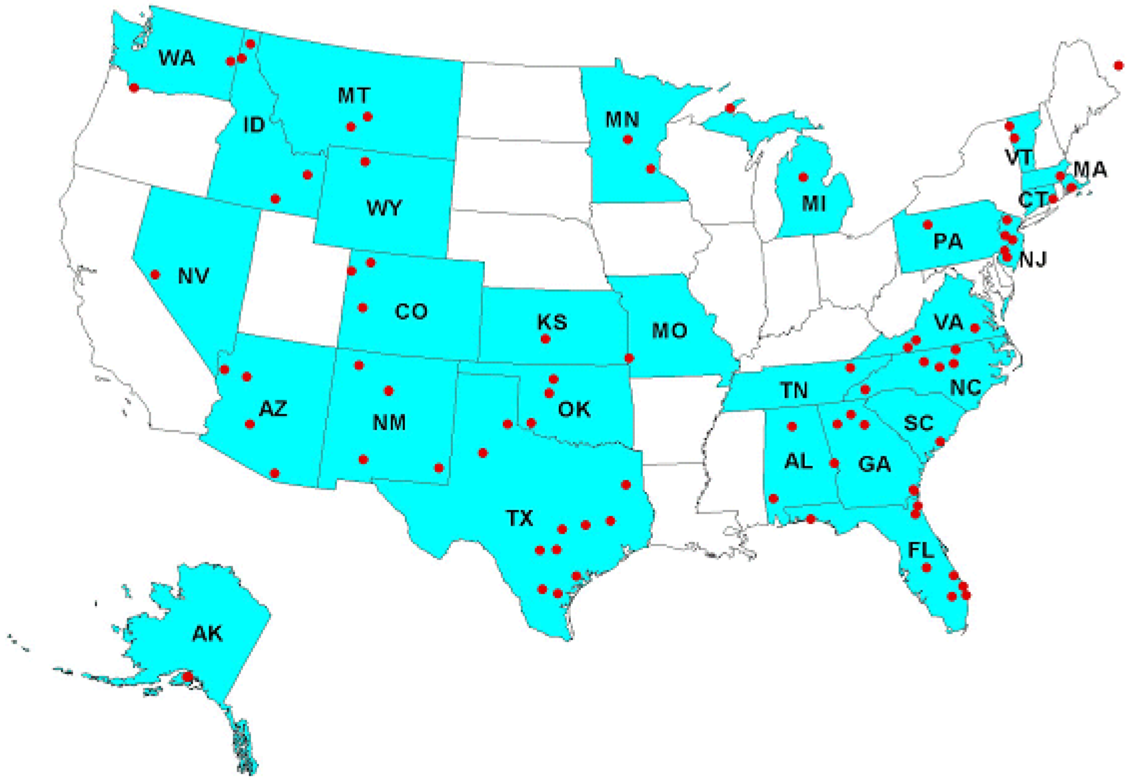


Figure 3 Location of the Sections used in the New Pavement Calibration

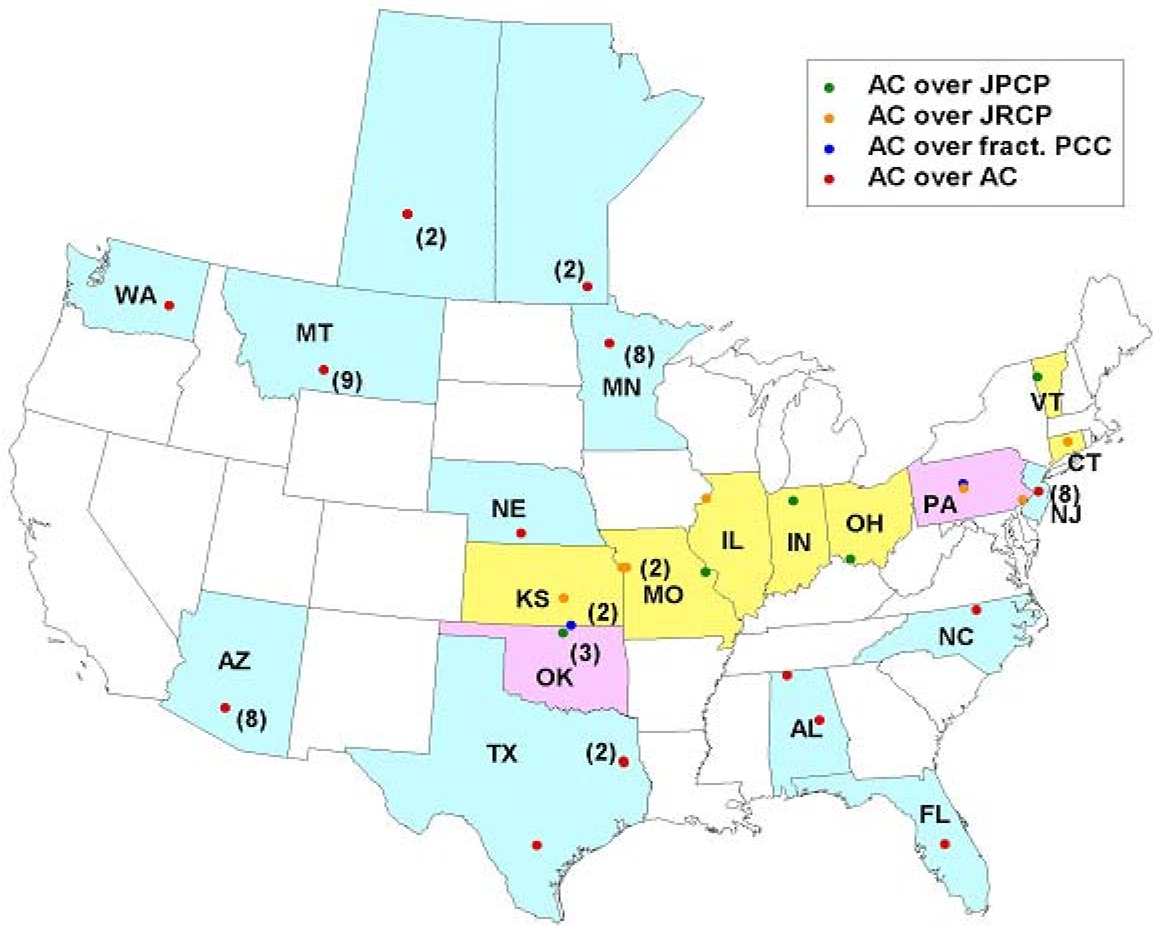


Figure 4 Location of the Sections used in the Rehabilitation Calibration Simulation Process

For the bottom-up cracking, the summation of the measured alligator cracking was divided by the total area of the lane (12'*500' = 6000 ft^2) to calculate the percentage area cracked. However, for the longitudinal cracking (top-down), the summation of the measured longitudinal fatigue cracking, in the LTPP database, was multiplied by 10.56 to convert the value from longitudinal feet per 500 feet to longitudinal feet per mile. It should be recognized that a very important set of assumptions is contained in the above description of cracking. Implicit within the distress magnitude is the fact that bottom-up fatigue cracking results in "alligator cracking" distress alone and surface-down fatigue cracking is associated with "longitudinal cracking". These are important assumptions that need to be remembered during the field calibration process.

Simulation Process

After selecting the sections suitable to be used for the calibration and collecting all the data needed to analysis each pavement section, the next step in the calibration process was to run the Design Guide software for all available sections. The output from the software was the accumulated damage for each section at the surface (or 0.5 inch deep) for top-down fatigue cracking and at the bottom of the asphalt layer (for the bottom-up cracking) for each month of the design life. However, before discussing the simulation runs, it is better first to discuss the procedure for the prediction of the fatigue cracking damage using the Design Guide software.

Fatigue Damage Prediction Procedure

The Design Guide software is user-friendly software, however the analysis part of the software is a complicated process. The design starts with inputting the data using the windows based input screens, then the analysis is run and finally the output is presented in excel worksheets. The procedure, which is needed to predict cracking for flexible pavements follows certain steps, these steps are summarized below:

- **Tabulate input data**: summarize all inputs needed.
- **Process traffic data**: the processed traffic data needs to be further processed to determine equivalent number of single, tandem, and tridem axles produced by each passing of tandem, tridem, and quad axles.
- **Process pavement temperature profile data**: the hourly pavement temperature profiles generated using EICM (nonlinear distribution) need to be converted to distribution of equivalent linear temperature differences to compute temperature gradients by calendar month.
- **Process monthly moisture conditions data**: the effects of seasonal changes in moisture conditions on base and subgrade modulus.
- **Sub layering of Pavement Structure**: the pavement structure is subdivided into smaller sublayers to account for changes in temperature

and frequency in the asphalt layers, as well as significant moisture content changes in unbound layers.

- **Calculate stress and strain states**: calculate tensile strains corresponding to each load, load level, load position, and temperature difference for each month within the design period at the ***surface*** and ***bottom*** of each asphalt layer. These depth positions (surface and bottom) are used in the top down (longitudinal) fatigue: surface and the bottom up (alligator) fatigue: bottom. Using material modulus and Poisson's ratio; determine the elastic strains at each computational point. Calculate damage for each sub-season and sum to determine accumulated damage in each asphalt layer.
- **Calculate fatigue cracking**: calculate the cracking for each layer from the damage calculated.

A detailed step-by-step procedure is given below:

Step 1: Tabulate input data

All input data required for the prediction of fatigue cracking is presented in detail in Appendix EE.

Step 2: Process traffic data

The traffic inputs are first processed to determine the expected number of single, tandem, tridem, and quad axles in each month within the design period. As previously mentioned, Level-1 traffic is used in the calibration process. Level-1 traffic includes the actual traffic load axle spectra data for each section from the LTPP database.

Step 3: Process temperature profile data

A base unit of one month is typically used for damage computations in the flexible pavement analysis. In situations where the pavement is exposed to freezing and thawing cycles, the base unit of one month is changed to 15-days (half month) duration to account for rapid changes in the pavement material properties during frost/thaw periods. While damage computations are based on a two-week or monthly average temperature; the influence of extreme temperatures, upon AC stiffness, above and below the average, are directly accounted for in the design analysis. In order to include the extreme temperatures during a computational analysis period, the following approach is used in the analysis scheme.

The solution sequence from the EICM provides temperature data at intervals of 0.1 hours (6 minutes) over the analysis period. This temperature distribution for a given month (or 15-days) can be represented by a normal distribution with a certain mean value (μ) and the standard deviation (σ), $N(\mu,\sigma)$ as shown in Figure 5.

The frequency distribution of temperature data obtained using EICM is assumed to be normally distributed as depicted in Figure 5. The frequency diagram obtained from the EICM represents the distribution at a specific depth and time. Temperatures in a given month (or bi-monthly for frost/thaw) may have extreme temperatures (even at a low frequency of occurrence) that could be significant for fatigue cracking.

Using the average temperature value within a given analysis period, will not capture the damage caused by these extreme temperatures. In order to account for the extreme temperatures, upon fatigue, the temperatures over a given interval are divided into five different sub-seasons. For each sub-season, the sub-layer temperature is defined by a temperature that represents 20 % of the frequency distribution of the pavement temperature. This sub-season will also represent those conditions when 20% of the monthly traffic will occur. This is accomplished by computing pavement temperatures corresponding to standard normal deviates of -1.2816, -0.5244, 0, 0.5244 and 1.2816. These values correspond to accumulated frequencies of 10, 30, 50, 70 and 90 % within a given month.

Step 4: Process monthly moisture conditions data

EICM calculates the moisture content and corrects for the moisture change in all unbound layers (base / subbase / subgrade). Refer to NCHRP 1-37A documentations (16) for a detailed explanation of the method used to correct the unbound layer modulus.

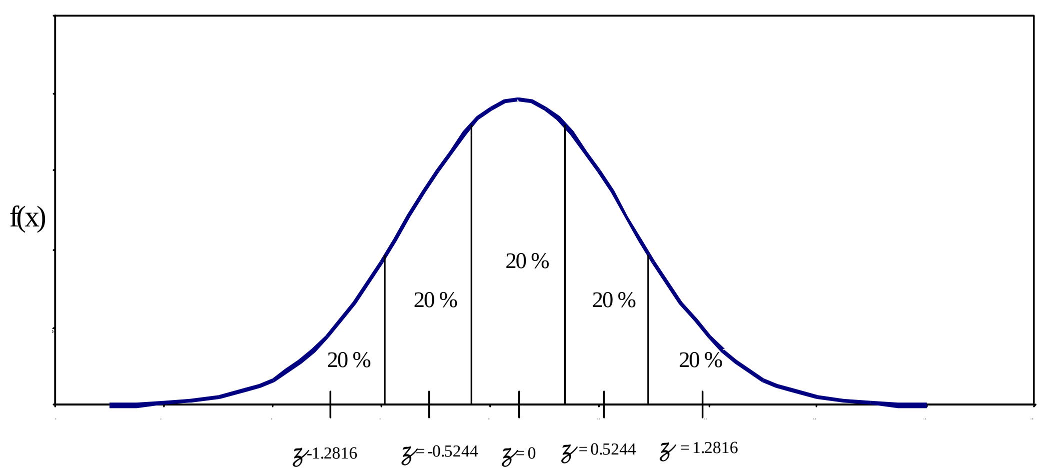


Figure 5 Temperature Distribution for a Given Analysis Period

Step 5: Pavement Sub layering

The pavement structure is sub divided into smaller sublayers to account for the changes in the temperature and frequency in the asphalt layers, as well as, the changes in the moisture content in the unbound base, subbase and subgrade layers. The pavement sublayer scheme is shown in Figure 6.

The first 1-inch of the asphalt layer is subdivided into two 0.5 and 0.5 inch sublayers. Then the asphalt layer is further subdivided into 1-inch sublayers to a depth of 4 inches. If the thickness of the asphalt layer is greater than 4 inches then a sublayer is added with a maximum thickness of 4 inches, which makes the total asphalt thickness to be 8 inches. The remaining thickness of the asphalt layer is taken as one final AC sublayer. For example if the AC layer thickness was 10 inches; then the asphalt sublayers would be 0.5, 0.5, 1,1,1,4 and 2 inches. All base, subbase and subgrade layers are subdivided as shown in Figure 6. If there is a chemically stabilized layer, these layers are not subdivided. Finally, it is important to recognize that no sublayering is conducted for any layer material greater than 8 feet from the surface. The maximum number of AC layers that can be used in the new design process is three; the maximum number of layers that can be input is 10 and the maximum number of sublayers, used in stress- strain computations, is 19.

Step 6: Calculate strain

It is necessary to use the pavement response model for the layered pavement structure to calculate potentially critical strains for all cases that needs to be analyzed.

The number of cases depends on the damage increment. The following increments are considered:

- Pavement age – by year.
- Season – by month or semi-month.
- Load configuration – axle type.
- Load level – discrete load levels in 1,000 to 3,000 lb increments, depending on axle type.
- Temperature – pavement temperature for the HMA dynamic modulus.

For damage computation, it is mandatory to “guess” all of the locations in the pavement system that may result in a critical response value. This is a very difficult problem to solve. For several different combinations of axle configurations, it is not possible to specify one location that will result in a maximum damage. To overcome this problem and to insure that the critical location is utilized in the damage analysis, the program internally specifies several computational points depending upon the axle type. It should be noted that the solution uses a maximum of four different axle types for design and analysis. Based upon the type of axles in the traffic mix, the program pre-defines the analysis locations where the maximum damage could occur because of mixed traffic. Once these locations are defined, the incremental damage is calculated at these locations for performance prediction within each computational analysis period to estimate the maximum damage.

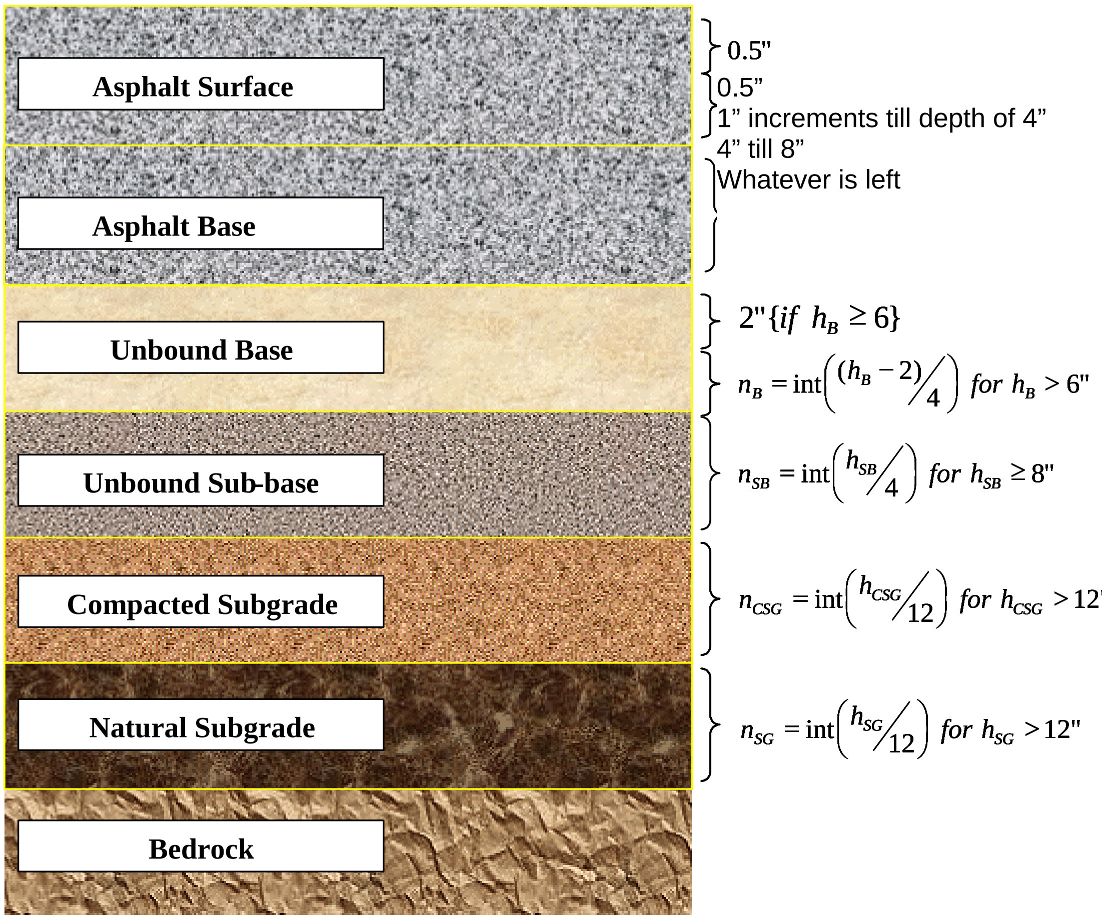


Figure 6 Layered Pavement Cross-Section for Flexible Pavement Systems (No Sub layering beyond 8 Feet).

The analysis location defined below is applicable for both the layer elastic analysis (JULEA) and the FEM approach. However, the computation of responses at these critical locations depends upon the pavement response model. For the layered elastic analysis (JULEA), the principle of superposition is used to account for axles within the specific axle type (single, tandem, tridem, or quad). Because, for any axle type, the response in only obtained for dual wheels on the single axle and the effect of other wheels within the axle configuration is obtained by superposition. This is done to obviously minimize the number of JULEA runs for the layer elastic analysis. The only restriction with this approach is that all wheels in the gear assembly have the same load and tire pressure. Figure 7 shows the analysis locations for the four axle types used for the general traffic analysis. In addition, the figure also shows the approach used for the estimation of critical response.

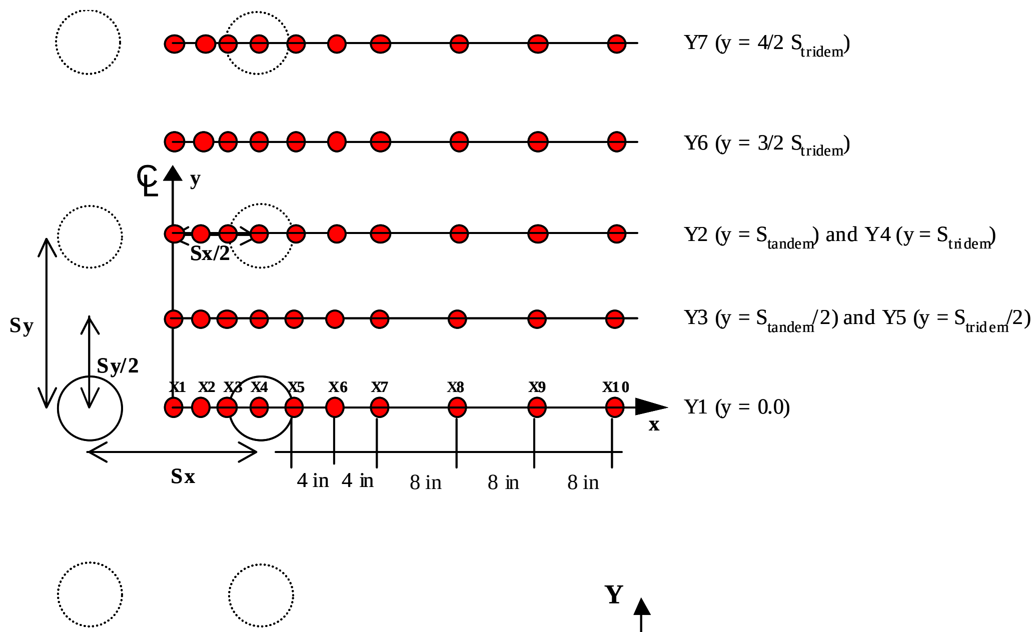
Before explaining the approach used for determination of critical response, it is important to understand the location of the analysis points. Below is the description of "X" and "Y" locations shown in Figure 7.

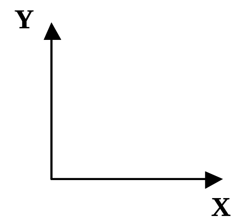
X-Axis Locations

$X1 = 0.0$ {center of dual tires/tire spacing}
$X2 = ((T_{spacing}/2) - T_{radius})/2$ {$T_{spacing}$ = tire spacing; T_{radius} = tire contact radius}
$X3 = (T_{spacing}/2) - T_{radius}$
$X4 = T_{spacing}/2$
$X5 = (T_{spacing}/2) + T_{radius}$
$X6 = (T_{spacing}/2) + T_{radius} + 4$ in
$X7 = (T_{spacing}/2) + T_{radius} + 8$ in
$X8 = (T_{spacing}/2) + T_{radius} + 16$ in
$X9 = (T_{spacing}/2) + T_{radius} + 24$ in
$X10 = (T_{spacing}/2) + T_{radius} + 32$ in

Y-Axis Locations

Y1: $y = 0.0$ {center of dual tires/tire spacing}
Y2: $y = S_{tandem}$ {tandem axle spacing}
Y3: $y = S_{tandem}/2$
Y4: $y = S_{tridem}$ {tridem/quad axle spacing)
Y5: $y = S_{tridem}/2$
Y6: $y = S_{tridem}3/2$
Y7: $y = S_{tridem}4/2$





Computed Responses

- Single
  - Response 1 = Y1
- Tandem
  - Response 1 = Y1 + Y2
  - Response 2 = 2 * Y3
- Tridem
  - Response 1 = Y1 + 2 * Y4
  - Response 2 = 2 * Y5 + Y6
- Quad
  - Response 1 = Y1 + 2 * Y4 + Y7
  - Response 2 = 2 * Y5 + 2 * Y6

Figure 7 Schematics for Horizontal Analysis Locations Regular Traffic

The approach developed results in a total of 70 analysis points (10 X-locations with 7 Y-locations) for 4 axle types. These computational points are used for each critical depth (Z axis) used in both the fatigue and permanent deformation distresses. These analysis locations are used for the determination of the critical stresses/strains for the damage calculations. It should be remembered that for a given axle type the response at these analysis locations is determined by the dual wheels only, and not by the entire wheel configuration on a specific axle type.

The simplest case is that of a single axle with dual wheels, where no superposition is required. Along the x-y plane, the designated analysis locations are X1 to X10 along the Y1 (y = 0.0), as shown in Figure 7. The response is measured along these points to determine the critical value. The critical location in the one at which the response (stress/strain) is maximum. This is shown as Response 1, under the single axle category. For tandem axles, a total of 30 analysis points are needed. These points are along Y1, Y2, and Y3. Y1 is set at y = 0 (over the x-axis), Y2 is set at $y = S_{tandem}$ (tandem axle spacing), and Y3 is set at $y = S_{tandem}/2$. It should be recalled that the stresses/strains are only estimated for the dual wheels at these analysis locations. For tandem axles, it is very obvious because of the geometry that the maximum response will be either along the axis under the twin wheels (along Y1 or Y2) or along Y3. Since the responses along Y1 and Y2 should be same, the response is only estimated at one of these locations. The two responses for the tandem axle configuration are shown in Figure 7 as Response 1 and Response 2. Response 1 will be the summation of stresses/strains along Y1 (wheel location at y=0) and Y2 (wheel location at $y = S_{tandem}$), whereas Response 2 will be two times Y3 (accounting for two axles at $y = S_{tandem}/2$). The critical stress/strain along x-axis is determined by comparing the two responses at the same x-axis distance. That is, the two X1 values along y = 0 and at $y = S_{tandem}/2$ are compared for maximum value. Comparing all the paired values will then define the critical response for damage calculations along the x-axis.

Similarly, two sets of responses are estimated for tridem and quad axle configurations. For the tridem axle, a total of 40 analysis locations is used while 50 locations are required for quad gear.

As noted, this discussion only relates to the analysis locations in the x-y plane. At these horizontal (x, y) locations, critical responses are also determined at several depth locations depending upon the distress type.

Given a particular layered pavement cross section, the tensile strains (in both the direction of traffic (y) and perpendicular to traffic (x)) at the bottom of each AC or chemically stabilized layer / sublayer as well as the surface is defined by the knowledge of the three-dimensional stress state and the elastic properties (modulus and Poisson's ratio) of the AC layer in question.

The complex moduli of asphalt mixtures are employed in the Design Guide via a master curve. Thus, E^* is expressed as a function of the mix properties, temperature, and time of the load pulse. Knowledge of the predicted tensile strain at any point, along with the layer dynamic modulus and N_f repetition relationship, allows for the direct calculation of the damage for any asphalt layer, after N repetitions of load, to be computed.

Estimation of fatigue damage is based upon Miner's Law, which states that damage is given by the following relationship.

$$\sum_{i=1}^{T} D_i = \frac{n_i}{N_{fi}} \tag{11}$$

where:
D = damage
T = total number of periods
n_i = traffic for period i
N_i = allowable failure repetitions under conditions prevailing in period i

Wander Effect

One of the inputs required in the design process is the lateral vehicle wander, in inches. Wander is the lateral traffic distribution over a pavement cross section, and it accounts for the fact that not all vehicles stress the pavement surface at the exact same point. The amount of lateral wander directly affects the fatigue and the permanent deformation within the pavement system. An increase in wander will result in more fatigue life and less permanent deformation within the pavement system. It is not practical to assess the exact distribution of wander; however, a good approximation is to assume that the wander is normally distributed. The standard deviation for the normal distribution plot represents the wander in inches.

Because Miner's Law is linear with traffic, damage distribution, considering wander, is computed from the fatigue damage profile obtained that has no wander (wander = 0 inch). The approach is better explained in Figure 8.

In Figure 8, plot "A" shows the pavement structure with a dual wheel centered at location 1. In this example, 5 points are used to define the damage profile due to wander effect (locations 1, 2, 3, 4, and 5 on the figure); however, within the Design Guide program 11 points are used to define the damage profile. As mentioned earlier, 10 lateral points (Figure 7) are used for damage calculations. These points are sufficient to define the damage profile. Plot "B" shows the actual damage profile for a wander value of zero predicted by the design program.

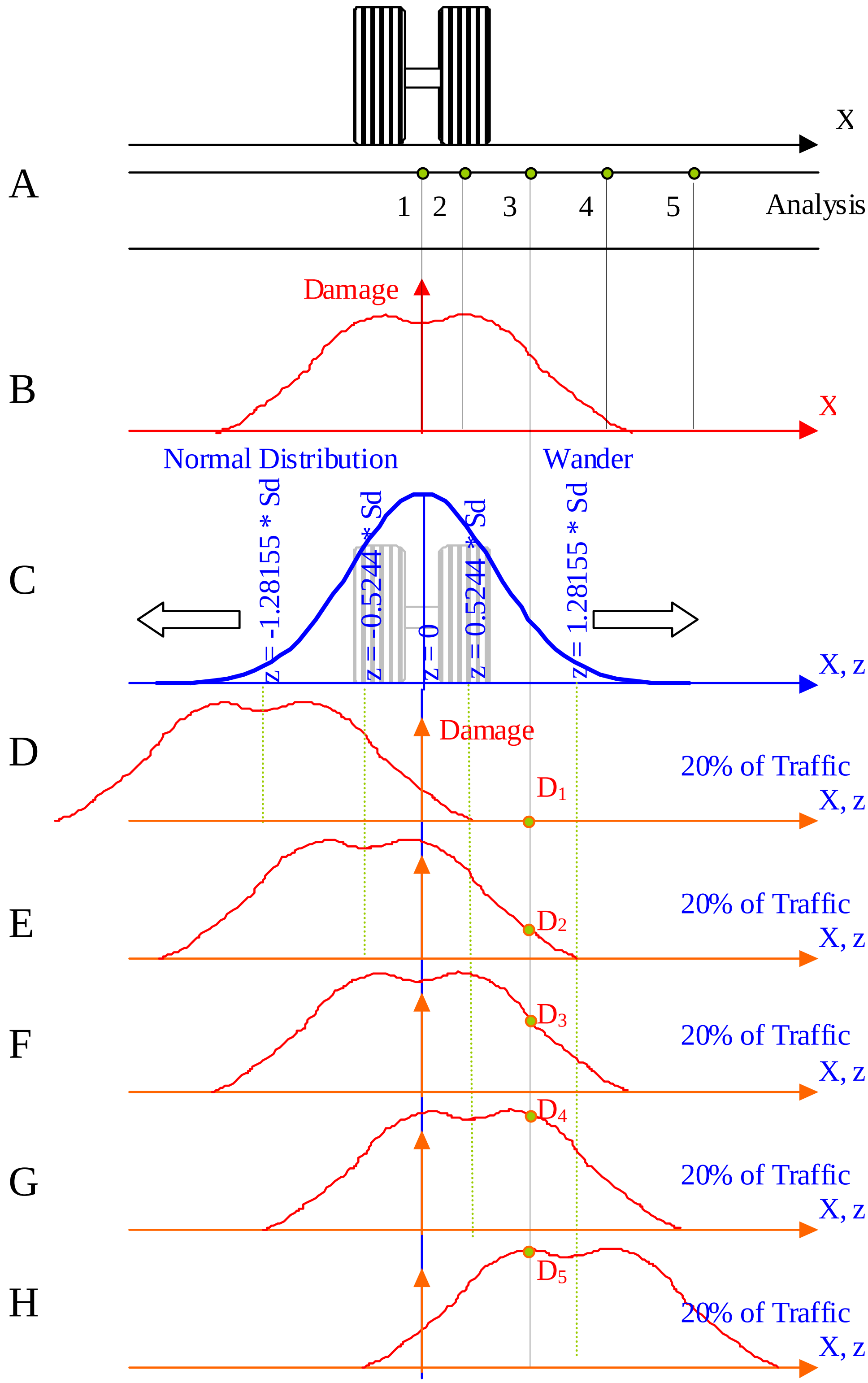


Figure 8 Fatigue Analysis Wander Approach.

If no wander is used, the maximum value from this damage will define the fatigue life. Plot "C" in this figure shows the wander distribution and is assumed to be normally distributed. The spread of the distribution is dependent upon the standard deviation value entered by the user.

A higher standard deviation or higher wander value will result in a larger spread. In this plot (normal distribution plot) the area under the curve can be divided into five quintiles, each representing 20 percent of the total distribution. For each of these areas, a representative x-coordinate is found by multiplying the standard normal deviate "z" by the wander (standard deviation). Each of the normal deviates will represent accumulated areas equivalent to 10, 30, 50, 70, and 90 percent of the distribution.

Therefore, it is assumed that, for 20 percent of the traffic, damage distribution will be centered at location equal to –1.28155 S_d, where S_d is the wander. For this situation (plot D), damage at location 3 is D_1. Since D_1 is 0 for this case, no fatigue damage occurs at location 3. The next plots (plots E through H) show damage distribution centered at z = -0.5244, 0, 0.5244, and 1.28155. Each represents the situation occurring for 20 percent of the traffic. Damage for cases is D_2, D_3, D_4, and D_5, respectively. Thus, the total damage at location 3 can be computed as:

$$D = 0.2 \times D_1 + 0.2 \times D_2 + 0.2 \times D_3 + 0.2 \times D_4 + 0.2 \times D_5 = 0.2 \times \sum_{i=1}^{5} D_i \qquad (12)$$

D_i (each analysis location) is determined using polynomial or linear interpolation.

Simulation Runs

In establishing the fundamental fatigue model that was to be used for the field calibration-validation study, the fatigue failure model has three coefficients, as shown in equation 13. Table 3 shows the two models considered in the study.

$$N_f = \beta_{f1} k_1 (\varepsilon_t)^{-\beta_{f2} k_2} (E)^{-\beta_{f3} k_3} \qquad (13)$$

where:

N_f	= Number of repetitions to fatigue cracking.
ε_t	= Tensile strain at the critical location.
E	= Stiffness (dynamic modulus) of the material.
k_1, k_2, k_3	= Laboratory regression coefficients.
β_{f1}, β_{f2}, β_{f3}	= Calibration parameters.

Table 3 Fatigue Cracking Models used in the Study

Factor	Shell Oil	Asphalt Institute MS-1
k_1	$\left(1+\frac{13909E^{-0.4}-1}{1+\exp^{(1.354h_{ac}-5.408)}}\right)*$ $(0.0252PI-0.00216PI(V_b)+0.00673V_b-0.0167)^5$	$0.004325*$ $10^{4.84\left(\frac{V_b}{V_a+V_b}-0.69\right)}$
k_2	5	3.291
k_3	1.4	0.854

For each coefficient factor, a calibration factor (β_{fi}) was introduced to eliminate the bias and scatter in the predictions. It is these calibration factors, β_{fi}, which are used to calibrate the fatigue-cracking model to actual field performance.

The simulation runs were done by running the software for a combination of values of the calibration factors β_{f2}, β_{f3}. Then the reasonable solution was optimized using β_{f1} as a function of the total asphalt concrete layer thickness. This last correction was used to compensate for the crack propagation phase of the fatigue cracking phenomena.

The runs using the MS-1 model were conducted for values of 0.8, 1.0 and 1.2 for the calibration factor on the strain (β_{f2}), while the values of 0.8, 1.5 and 2.5 were used for the modulus calibration factor (β_{f3}). Additional runs were used in the simulation to check on the sensitivity of the factors such as using the original factors of the equation (using calibration factors of 1.0 on both the strain and the modulus). For the Shell Oil model β_{f2} and β_{f3} had the same values of 0.9, 1.0 and 1.1. These values for the two calibration factors were somewhat guided based on available fatigue models in the literature. The lab regression coefficients (k_2, k_3) (not the calibration factors) ranges, found in the literature, were from 2.5 to 5 for the strain and from 0.8 to 2 for the modulus.

The simulation runs were completed on both the Shell Oil and the Asphalt Institute (MS-1) fatigue models. Both models were evaluated in the calibration process to ascertain which model form (equation) methodology would provide the most accurate solution for the field calibration process. Annex B and Annex C provides plots / data of the simulation runs for the bottom-up fatigue cracking using both Shell Oil and MS-1 models for all combinations of the strain and the modulus calibration factors grouped by total asphalt layer thickness. Annex B shows the bottom-up cracking damage predictions using the Shell Oil equation, while, Annex C shows the bottom-up cracking predicted damage using the MS-1 equation. Similarly Annex D and Annex E shows the predictions for the top-down fatigue damage, where Annex D provides the Shell Oil equation results, while Annex E shows the MS-1 model results. In the following section the results will be discussed and analyzed for the final step of the calibration process.

82 sections out of the 94 new (LTPP) sections were selected for the fatigue simulation as they contained fatigue-cracking data in the database. The 82 sections were located in 24 different states with different climatic location. The average running time of the program was 1.5 min per year within the design life using a 2 GHz Pentium 4 processor. This averaged about half an hour running time per section. This, in turn, resulted in a total computer running time of approximately 820 hours (2 models *10 simulations *82 sections *0.5 hour) for a single calibration trial for fatigue. This does not include the time taken to input the data in the program.

It must be noted that the calibration process was not really a single run of 820 hours. Many, sets of calibration runs were conducted. Many factors were responsible for the numerous runs conducted. The majority of these individual calibration runs were caused by bugs/errors in the program or erroneous input data (like traffic). These problems, which were subsequently discovered after the “Final” calibration, necessitated that the results be completely disregarded and the calibration process be redone. Obviously, all of the results shown here are the results of the last final set of runs after fixing all the bugs and errors.

Coefficient Selection

Ten different simulation runs were done using the 82 fatigue sections. Detailed plots showing the results of each run grouped by asphalt thickness for bottom-up fatigue by both the Shell Oil model and the MS-1 model are given in Annex B and C. Annex D and E provides simulation data /plots for top-down cracking.

The Shell Oil runs were done using the modified model (equation 8) for both constant stress and constant strain. However, the MS-1 model was used in its original form without any modification for all thickness of asphalt. The MS-1 fatigue model, modified with the appropriate β_{fi} factors, was used to calculate the damage percentage. These predicted damage percentage estimates were then plotted against the measured fatigue cracking in the field for each section.

A very important parameter was studied, which is the percentage damage when the cracking starts to appear. As explained earlier in this chapter, the cracking phenomena is divided into two stages: cracking initiation and crack propagation. During the crack initiation stage the damage increase while no cracking is observed. However, when the damage reached a certain percentage the crack can be seen and starts to propagate in the asphalt layer. Another set of variables studied were the range of the predicted damage and the scatter of the damage by AC layer thickness.

The results of the simulation runs for the Shell Oil bottom-up fatigue cracking are shown in Table 4. From the tables it can be seen that changing the β_{f2} and β_{f3} coefficients result in a big shift in the predicted damage values. This shift can be as large as 10^6 for the damage percentage.

The simulations runs results for the Shell Oil model, Table 4, show that the range of the damage values was very high. Also, the damage percentage at which the cracking would start propagating in the asphalt layer could not be identified and it was also found to depend greatly on the thickness of the AC layer. This can also be confirmed from Figure 9, which shows the plot of the predicted percentage damage using the Shell Oil model versus the measured percentage alligator cracking. All the calibration factors (β_{f1}, β_{f2} and β_{f3}) used for prediction of the damage shown in Figure 9 were 1.0.

Table 4 Shell Oil Bottom-Up Fatigue Damage Results

Combination of β_{f2} and β_{f3}	Minimum Damage (%)	Maximum Damage (%)	Damage (%) @ Start of Crack Propagation
0.9,0.9	0.5557	255,200	N/A
0.9,1.0	3.53	1,586,000	N/A
0.9,1.1	22.4	9,893,000	N/A
1.0,0.9	0.0027	2,645	N/A
1.0,1.0	0.0171	16,330	N/A
1.0,1.1	0.1084	101,300	N/A
1.1,0.9	1.4E-05	43.4	N/A
1.1,1.0	0.000085	286.4	N/A
1.1,1.1	0.00054	1,903	N/A

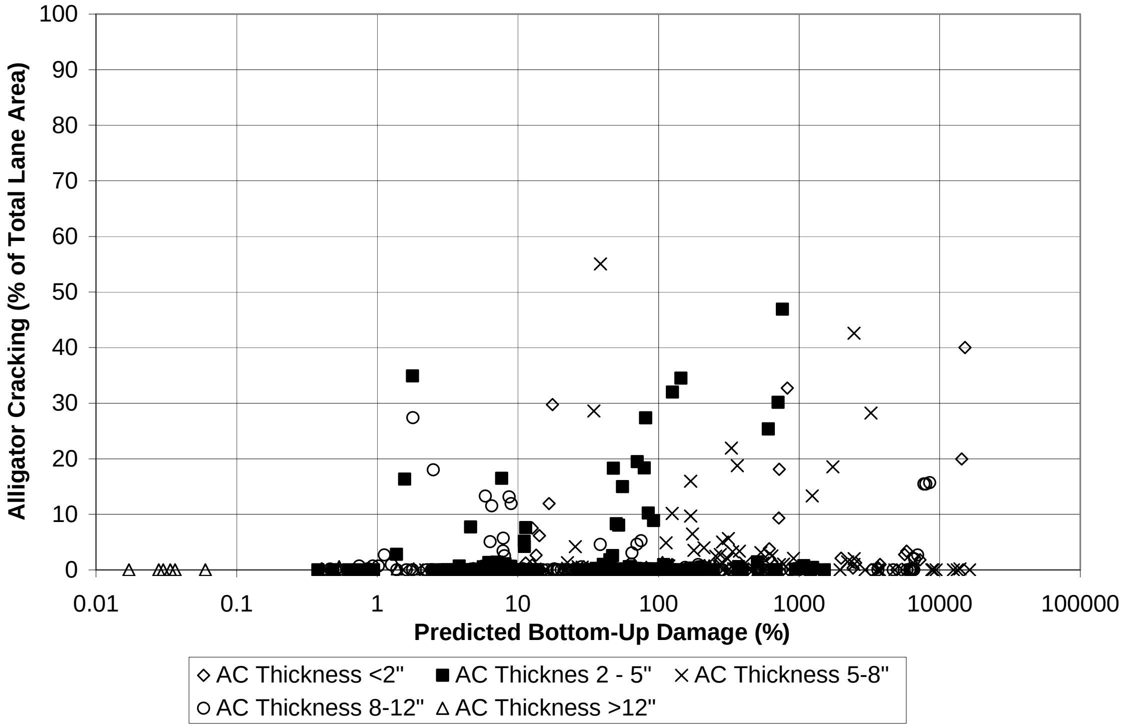


Figure 9 Shell Oil Predicted Damage vs. Measured Alligator Cracking (β_{f1} = 1.0, β_{f2} = 1.0, β_{f3} = 1.0) (Lane Area = 6000 ft^2)

From the initial analysis, the MS-1 fatigue model showed promising trends as seen in Table 5, the range of the predicted bottom-up damage is still high, but the percentage damage at which the cracking starts was easily identified. The combination of calibration factors of β_{f2} = 1.2 and β_{f3} = 1.5 provided a damage percentage of about 100 % when the cracking starts to propagate.

For the MS-1 model, the original data appeared to indicate that there were two separate groups in the plot: a group with thickness less than 4 inches and the other with asphalt thickness greater than 4 inch. This finding was very important as it confirmed the fact that constant strain (less than 4 inches) was necessary to be incorporated into the MS-1 constant stress model. Figure 10 shows the plot of the initial percentage damage versus the measured alligator fatigue cracking for the MS-1 model form (without the constant strain modification). The "outliers" for the thin AC sections are very evident in the figure and pointed out the necessity to adjust the MS-1 model for thinner AC layers. In Figure 10 the β_{fi} calibration factors used for the MS-1 model were β_{f1} = 1.0, β_{f2} = 1.2 and β_{f3} = 1.5. The results of the other simulation runs are provided in Annex C.

By examining both the preliminary results of the Shell Oil and the MS-1 models it was clear that the Shell Oil model possessed more scatter and did not possess any definite trends to follow. However, the MS-1 model had much less scatter and resulted in a definite trend between damage and cracking for sections greater that 4" –6" AC layers and thin AC sections (less than 4"). Based upon this initial study, it was concluded that MS-1 model was a more acceptable model for the prediction of the fatigue damage percentage for the 2002 Design Guide.

Table 5 MS-1 Bottom-Up Fatigue Damage Results

Combination of β_{f2} and β_{f3}	Minimum Damage (%)	Maximum Damage (%)	Damage (%) @ Start of Crack Propagation
0.8,0.8	30.5	2,497,000	7,000
0.8,1.5	80,110	9.5E+09	2.0E+07
0.8,2.5	6.3E+09	1.6E+15	5.0E+12
1.0,0.8	0.025	9,771	10
1.0,1.0	0.24	102,000	200
1.0,1.5	65	37,540,000	50,000
1.0,2.5	5,020,000	6.1E+12	7.0e+09
1.2,0.8	2.2E-05	43.6	0.02
1.2,1.5	0.055575	124,042	100
1.2,2.5	4,267	2.4E+10	1.0E+07

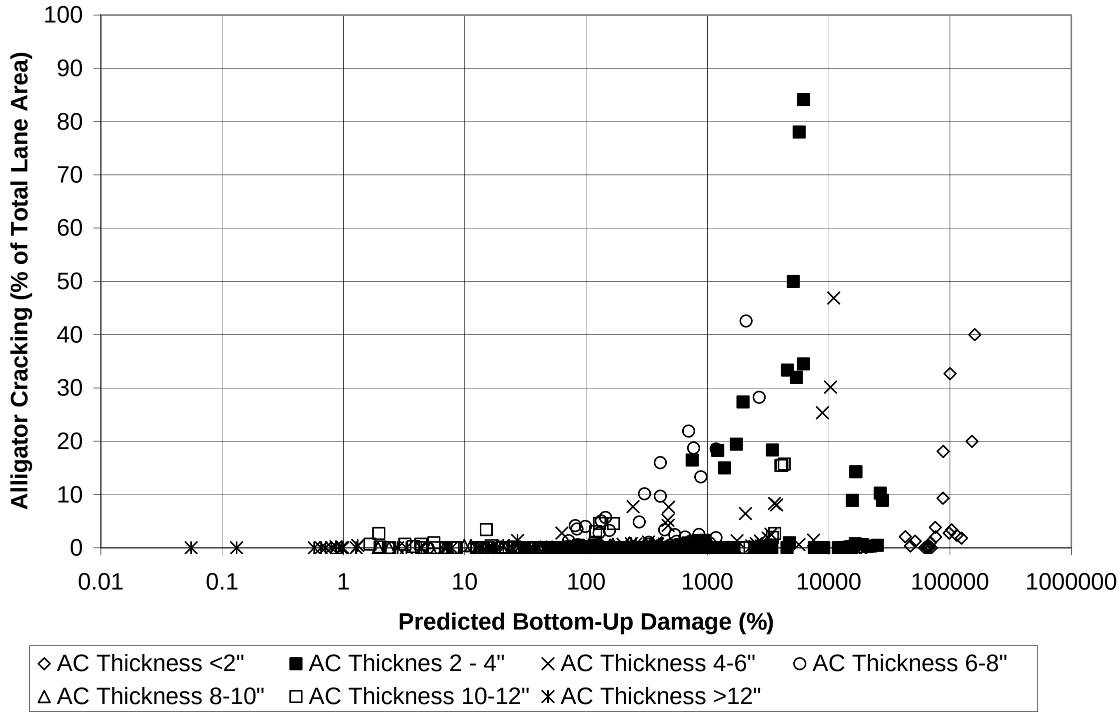


Figure 10 Asphalt Institute (MS-1) Predicted Damage vs. Measured Alligator Cracking (β_{f1} = 1.0, β_{f2} = 1.2, β_{f3} = 1.5) (Lane Area = 6000 ft^2)

Identical conclusions were found for the top-down cracking when the Shell Oil and MS-1 models were compared as shown in Figure 11 and Figure 12 (using the same calibration factors β_{f1}, β_{f2} and β_{f3} as mentioned earlier for the alligator cracking). The scatter of the predicted surface-down damage is much less in the MS-1 model than when using the Shell Oil model. The surface-down cracking mechanism used in this study has been noted to be hypothesized as a similar tensile strain fatigue failure as the more classical alligator cracking. That is why the same fatigue cracking model and calibration factors used for the bottom-up cracking were used for the surface-down cracking. However, the shift function (as a function of the AC layer thickness) is needed to correct for the constant strain effect, which is not included in the MS-1 model.

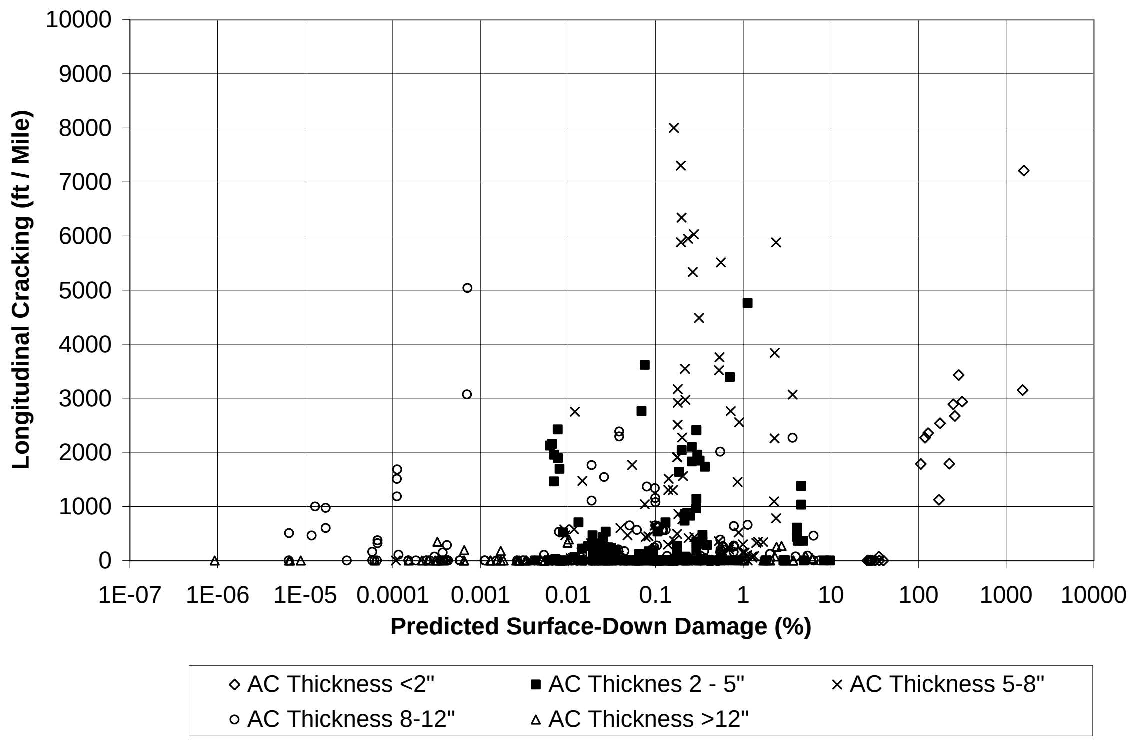


Figure 11 Shell Oil Predicted Damage vs. Measured Longitudinal Cracking (β_{f1} = 1.0, β_{f2} = 1.0, β_{f3} = 1.0)

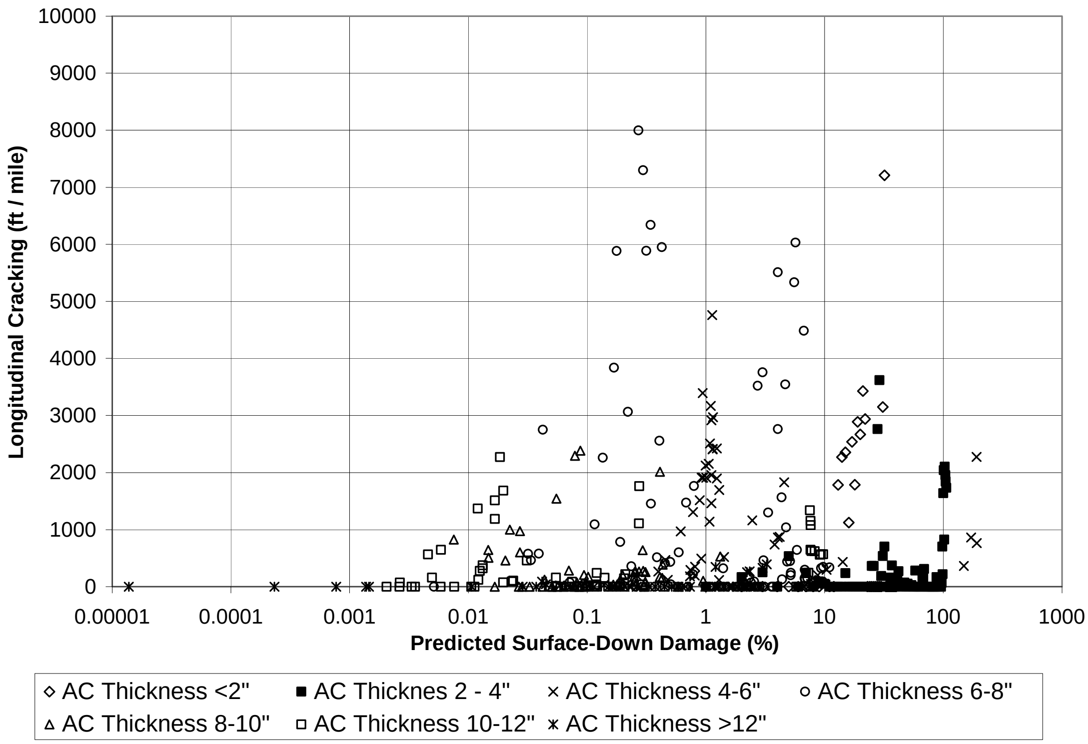


Figure 12 Asphalt Institute (MS-1) Predicted Damage vs. Measured Longitudinal Cracking (β_{f1} = 1.0, β_{f2} = 1.2, β_{f3} = 1.5)

Bottom-Up Fatigue Cracking Calibration

Once the initial model form was selected, the next step of the calibration process was to find the most accurate transfer function, which will predict damage relative to the measured field cracking observed. This section presents the final calibration of the bottom-up (alligator) cracking while the top-down cracking (longitudinal) is discussed in the following section. The final step of the calibration includes the analysis of field cracking data to check the factors and the trends of the alligator cracking measured in the field. The shift function, to correct for the constant strain in the fatigue-cracking model for thin AC sections is then presented. Finally the final transfer function, which correlates predicted damage to the measured alligator cracking, is presented.

Analysis of Measured Alligator Cracking Data

To calibrate distress models, field data must be checked for general reasonableness and any trends from these data should be examined. Any trends with the measured data should be compared to the calibration results trends to assess the reasonableness of the calibrated model. The database from the LTPP (12) (Long Term Pavement Performance) provided the capability to do these comparisons. The data was extracted from the LTPP database provided in the DataPave (version 3) software.

Alligator fatigue cracking data was collected from all available new sections having fatigue cracking in the LTPP database. The total number of sections used was 640 sections. Each section contained multiple data points as a time series of alligator cracking. The total number of points used in the forgoing study was 1897 data points. The LTPP database provided fatigue-cracking data according to severity level (low, medium and high severity) in each LTPP section. Each LTPP section has a length of 500 feet. In this research work, as mentioned earlier, the researchers were instructed to utilize the total of all three-fatigue cracking severity values, without using any weighting scheme. This value was then divided by the total area of the lane (12'*500' = 6000 ft^2) to calculate the percentage area cracked. At the same time, the thickness of all the asphalt concrete layers, for each section, was extracted from the database. The thickness was then added to get the total thickness of asphalt concrete layers for each section.

The frequency of the total asphalt layer thickness for the LTPP sections analyzed is plotted in Figure 13. The frequency of the asphalt layer thickness indicates that the 66 % of the sections built have a total asphalt layers thickness between 2 and 10 inches. Only 6% were less than 2 inches in thickness while 28 % were built with thicknesses greater than 10 inches.

Figure 14 shows the plot of the total alligator cracking percentage from the 640 LTPP sections to the total asphalt thickness. Figure 14 also shows that the alligator cracking in all of the LTPP sections analyzed, reaches a maximum damage (cracking) level at an asphalt layer thickness of 4 – 6 inches. This analysis also indicates a high percentage of fatigue cracking for thin (AC = 2 inches) sections. The percent cracking is very high and reaches a value of about 65% cracking (based on 117 sections).

Figure 15 shows the frequency distribution of the percentage alligator cracking. About 85% of the data points found in the database had alligator cracking less than 10%. This is primarily due to the fact that many highway agencies do not allow roadways to reach any significant level of cracking before some kind of maintenance will be performed to repair the cracking. In addition it should also be noted, that the numbers shown in the analysis represent time series of cracking early in the life of the pavement where fatigue cracking would not be expected.

Another major factor that affects fatigue cracking is the mean annual air temperature (MAAT). As shown in Figure 16 and Figure 17, the MAAT for the LTPP sections evaluated, ranges from about 29 ºF to about 77 ºF. The general expectation of the alligator cracking was that more cracking usually occurs in cold regions and less cracking in hot regions. However, the plots indicate that the occurrence and the amount of alligator cracking are very close for all regions and independent of the MAAT (site environment). Thus, the MAAT appears to have little to no significant influence on the measured alligator cracking reported in the LTPP database. The inference here is that pavement structures and material properties are more important in the fatigue process than MAAT. However, perhaps what is most critical to fatigue cracking is the interaction (dependency) of AC mix stiffness and the climatic condition at the design site. Thus by the proper selection of material quality (stiffness) the influence of temperature is mitigated or normalized as a salient design variable.

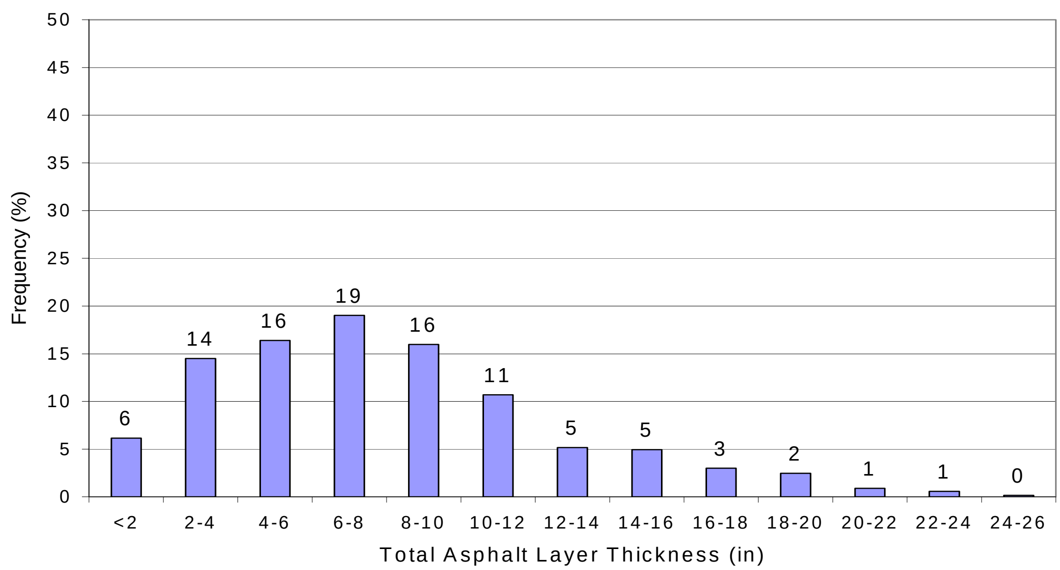


Figure 13 Frequency Distribution for the Total Asphalt Layer Thickness.

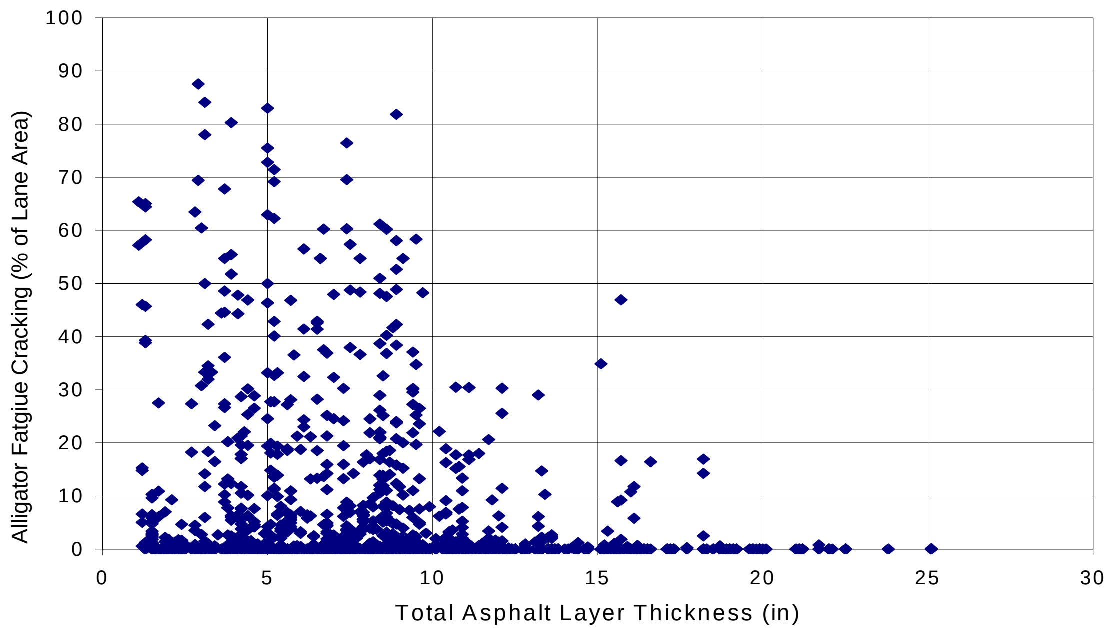


Figure 14 LTPP Alligator Cracking Data vs. Asphalt Layer Thickness

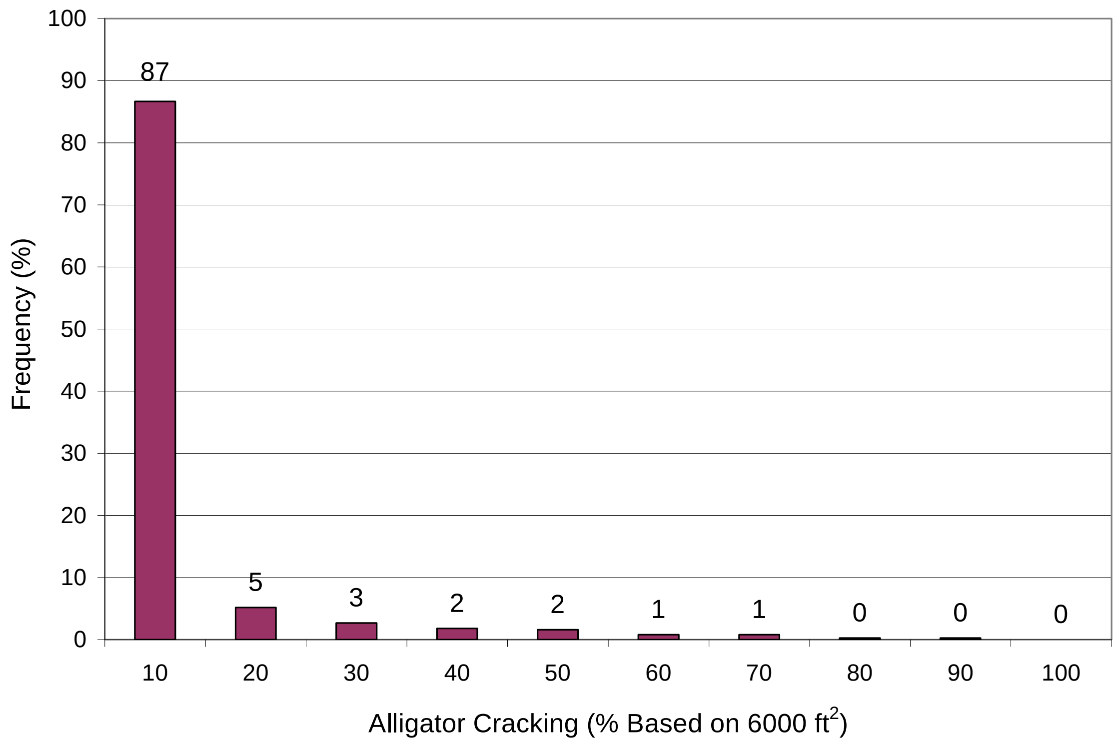


Figure 15 Frequency Distribution of Percentage Alligator Cracking

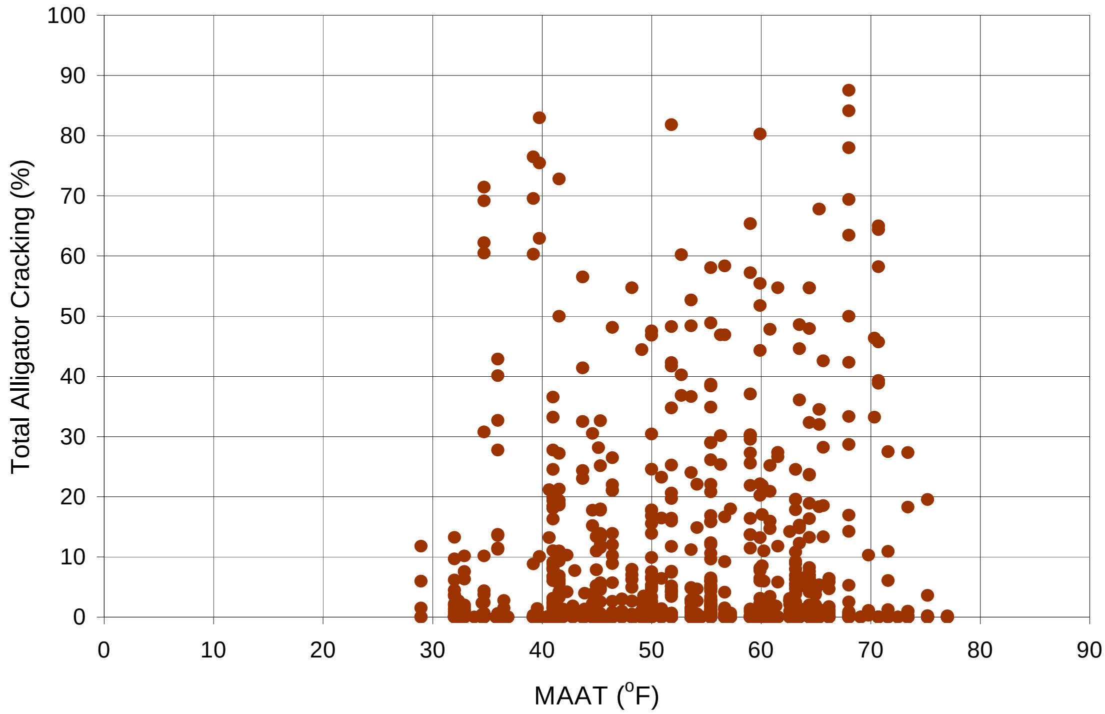


Figure 16 Alligator Cracking vs. Mean Annual Air Temperature

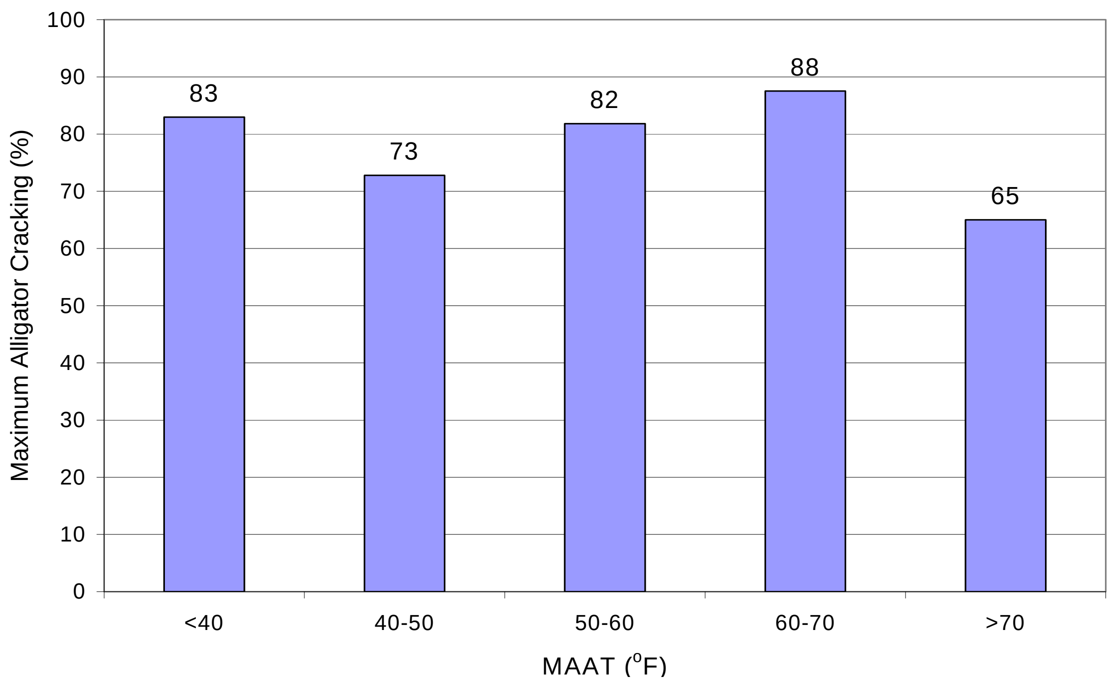


Figure 17 Maximum Alligator Cracking vs. Site Mean Annual Air Temperature Ranges

Calibration of the Fatigue Alligator Cracking Model

The next step of the calibration process is to derive an appropriate shift function relating asphalt thickness to damage and the cracking. The following section will discuss these two steps using only the MS-1 model selected in the initial study stage as the model of choice in the analysis. The MS-1 model is shown in equation 14

$$N_f = 0.00432 * C * \beta_{f1} \left(\frac{1}{\varepsilon_t} \right)^{3.291 * \beta_{f2}} \left(\frac{1}{E} \right)^{0.854 * \beta_{f3}} \tag{14}$$

In the previous equation (14) there are three calibration factors (β_{f1}, β_{f2} and β_{f3}), these factors needs to be estimated by minimizing the error in the prediction of the damage. β_{f1} would be a function of the AC layers thickness to shift the thin sections (constant strain). In addition to the estimation of these three alligator fatigue cracking calibration factors, a transfer function between the predicted damage and measured cracking is required to complete the calibration process.

The fatigue cracking – damage transfer function used in the calibration of the Design Guide alligator (bottom-up) fatigue cracking was assumed to take on the form of a mathematical sigmoidal function. The model form selected is in the form given in equation 15

$$F.C. = \left(\frac{6000}{1 + e^{C_1 - C_2 * LogD}} \right) * \left(\frac{1}{60} \right) \tag{15}$$

where:

$F.C.$ = fatigue cracking (% of lane area)
D = Damage in percentage
C_1, C_2 = regression coefficients

The 6000 in the alligator cracking – damage function is the total area of the lane (12 feet wide and 500 feet length). The (1/60) value is a conversion to obtain the cracking in percentage, not in square feet.

To find the regression coefficients C_1 and C_2 a Microsoft Solver numerical optimization routine was used. The optimization was set by first predicting the damage for each alligator cracking data point. An initial value was assumed for C_1 and C_2. Then by using the equation form given in equation 15, fatigue cracking was calculated from the predicted damage percentage. The predicted alligator fatigue cracking was then compared to the measured alligator cracking by finding the error between the two values. The errors are then squared and summed to get the total sum of squared error. Microsoft Excel Solver was then run to minimize the sum of squared errors by changing the C_1 and C_2 values for the first iteration. The new C_1 and C_2 values are then used as the input for the second iteration, and the same steps are repeated till the solution converges and the minimum total sum of squared errors is obtained. Finally, the Microsoft Solver is used again to set the arithmetic sum of errors to zero (by changing the C_1 and C_2 values again). This is done in order to eliminate any bias in the prediction. This optimization approach has been previously presented in Chapter 2 of this dissertation.

The alligator fatigue cracking calibration process can be summarized in the following steps:

1. Estimation of β_{f2} and β_{f3}
2. Finding the alligator fatigue cracking – damage transfer function by minimizing the error to get a final value of C_1 and C_2.
3. Finally, shifting thin sections to match with the thick sections. This is accomplished by associating β_{f1} to a function having the AC layers thickness as an independent variable.

In the following sections a step-by-step details of all the alligator cracking calibration process are discussed.

Estimation of β_{f2} and β_{f3}

As shown earlier ten simulation runs were conducted using different values and combinations of β_{f2} and β_{f3} as shown in Table 5. To compare these runs for different β_{f2} and β_{f3} values, a quick optimization was done to optimize the error in the alligator cracking – damage transfer function given in equation 15 using the bottom-up damage percentage predicted for each combination of β_{f2} and β_{f3} and the corresponding measured alligator cracking for each LTPP section used in this study. Table 6 shows the standard error calculated from each simulation run. The fitting of the predicted damage to calculate the alligator fatigue cracking, in this step, was done without any AC thickness shift for the damage.

Table 6 shows that as β_{f2} and β_{f3} value increased the standard error is reduced. The simulation run, which had a β_{f2} equal to 1.2 and β_{f3} equal to 1.5, provided a realistic prediction, in which the cracking starts to appear and propagate in the AC layer at a bottom-up predicted damage percentage of 100 %, the range of the damage was in the realistic range and the standard error is minimum. Accordingly, the calibration factors β_{f2} and β_{f3} were set at 1.2 and 1.5 respectively. However, the calibration factor β_{f1} still needed to be adjusted to shift the thin AC layer (constant strain sections less than 4 inches) to match the constant stress sections (greater than 4 inches AC thickness). The mathematical approach used to accomplish this objective will be explained later in this chapter.

Table 6 MS-1 Bottom-Up Fatigue Damage Standard Error

Combination of β_{f2} and β_{f3}	Standard Error
0.8,0.8	282.36
0.8,1.5	282.28
0.8,2.5	282.06
1.0,0.8	279.56
1.0,1.0	279.56
1.0,1.5	279.51
1.0,2.5	279.23
1.2,0.8	275.98
1.2,1.5	275.91
1.2,2.5	275.68

The revised MS-1 alligator fatigue-cracking model can then be written as shown in the following equation:

$$N_f = 0.00432 * \beta_{f1} * C\left(\frac{1}{\varepsilon_t}\right)^{3.9492}\left(\frac{1}{E}\right)^{1.281} \tag{16}$$

where:

$\beta_{f1} = \beta'_{f1} * k'_1$

$\beta'_{f1} =$ Numeric value

$k'_1 =$ Function of the AC layer thickness

In this equation the parameter β_{f1} has been introduced to provide a correction for thin asphalt layer thickness effects. However, before finding the relationship that represents β_{f1} as a function of the AC layers thickness, the function describing the measured alligator cracking – predicted bottom-up damage transfer function was found first using thick sections (AC layer thickness greater than 4 inches).

Alligator Fatigue Cracking – Damage Relationship

The correlation between the alligator cracking and damage was based on two assumptions:

- A sigmoidal function form is the best representative of the relationship between cracking and damage. This is an extremely reasonable assumption as the relationship must be "bounded" by 0 ft^2 cracking as a minimum and 6,000 ft^2 cracking as a maximum.
- The alligator cracking is 50% cracking of the total area of the lane (6000 ft^2) at a damage percentage of 100%.

The cracking – damage correlation was obtained using only sections, which had an AC thickness greater than 4 inches. This was because the MS-1 fatigue model was developed using the constant stress theory (thick AC sections). Also, it can be seen in Figure 10 that AC thicknesses greater than 4 inches were grouped together while sections with AC thickness less than 4 inches had a higher damage percentage. Sections, which have AC layer thickness less than 4 inches, were eventually shifted using the β_{f1} as a function of the AC thickness.

The sigmoidal function form given in equation 15 was used to correlate the fatigue cracking to the damage of an AC pavement. This function form has two coefficients (C_1 and C_2). In order to satisfy the second assumption previously noted the C_1 value must be equal to twice the value of C_2 but with a negative sign as shown in equation 17.

$$C_1 = -2 * C_2 \tag{17}$$

Also, the second assumption implied that the damage values should be multiplied by a factor of 0.004 in order to set 50% cracking at 100% damage. The main objective of this step is to find the values of C_1 and C_2 while satisfying the above listed two assumptions. In reality, only C_2 is needed and from equation 17, C_1 can be easily obtained.

The rate at which the crack initiates and then propagates in the pavement structure depends mainly on the thickness of the AC layers. That is why the relationship that correlates the fatigue cracking to the damage in the pavement should include the effect of the rate (slope) of cracking, which is a function of the AC layer thickness. C_2 was obtained from the relationship between the rate of cracking and the thickness of the AC layers.

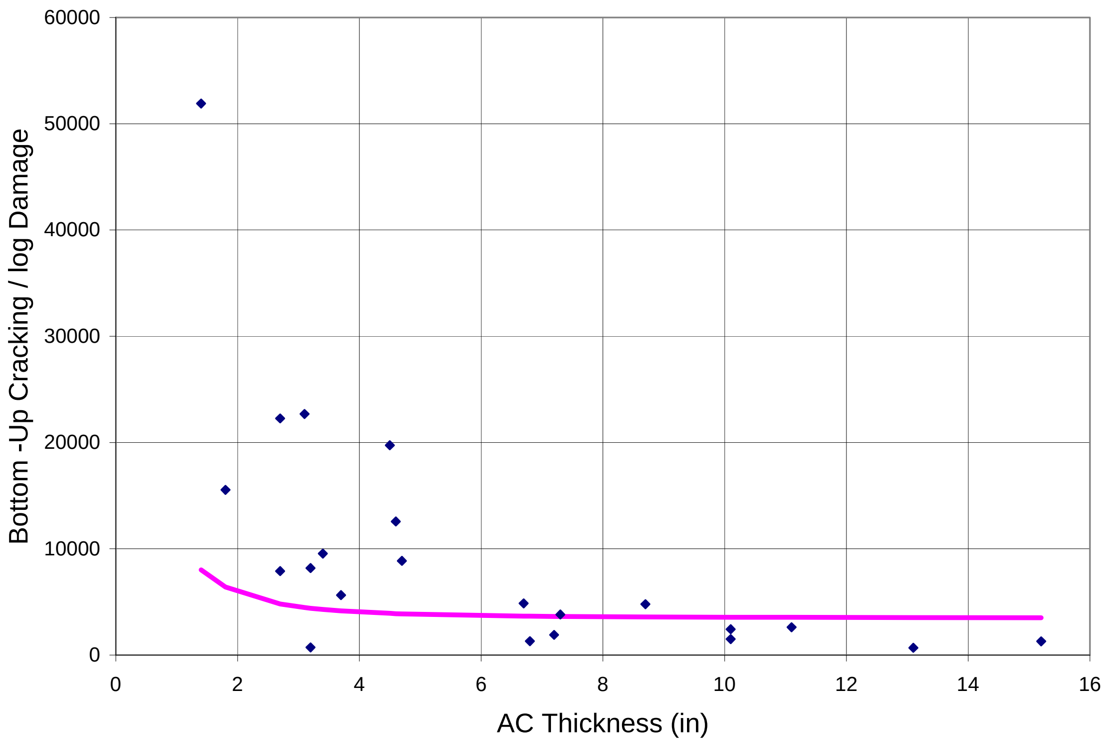


Figure 18 Ratio Between Bottom-up Cracking and Log Damage vs. AC Thickness

The rate of cracking was calculated from only 26 sections (from 82 sections) that developed significant cracking. Using two cracking values (a low and high cracking) and the time between these two crack levels, the rate of cracking was calculated, as shown Figure 18. A model was fitted in these data. The final form of this model is the C_2.

The final fitted model for C_2 is shown in the following equation

$$C_2 = -2.40874 - 39.748 * (1 + h_{ac})^{-2.85609} \tag{18}$$

By finding the C_2 then the transfer function is set and the only remaining issue is to shift thin section performance to match the thick ones.

Shifting Thin Sections

To find the equation for β_{f1} as a function of the AC layers thickness, the sections were first sorted by AC layers thickness. Four groups were identified:

1. Sections with an AC thickness less than 2 inches,
2. Sections with an AC thickness between 2 and 3 inches,
3. Sections with an AC thickness between 3 and 4 inches,
4. Sections with an AC thickness greater than 4 inches.

β_{f1} was divided into two parameter β'_{f1} and k'_1, as given in equation 19. The β'_{f1} is a number; it is not a function of any variable. However, k'_1 is a function of the AC layer thickness.

$$\beta_{f1} = \beta'_{f1} * k'_1 \tag{19}$$

As mentioned earlier, sections with AC layer thickness greater than 4 inches typically had a shift factor of 0.004. The remaining three groups had a higher damage value, with the highest damage for sections less than 2 inches thickness. Table 7 shows the maximum and minimum damage values predicted for the different AC thickness.

A shift factor was used to shift the damage for each of the thickness groups to match the fourth group (AC thickness greater than 4 inches). This shift factor was found manually for each group to satisfy the assumption that 50 % of the fatigue cracking occurs at 100 % damage. The shift factors adopted for each thickness group are shown in Table 7.

A sigmoidal function was then fitted for the shift factors obtained for each AC thickness group with the AC layer thickness as an independent variable. Figure 19 shows the sigmoidal function used to shift the thin sections for the calibration of the alligator fatigue (bottom up) cracking.

For the alligator fatigue (bottom up) cracking the "k'_1" parameter is given by the following equation:

$$k'_1 = \frac{1}{0.000398 + \dfrac{0.003602}{1 + e^{(11.02\text{-}3.49*\text{hac})}}} \tag{20}$$

where:

h_{ac} = Total thickness of the asphalt concrete layers.

The statistical summary for this model is:

Sum of error square = 1.92E-07

Standard error (S_e) = 0.00017

Table 7 Minimum and Maximum Damage (%) by AC Thickness

AC Thickness	Minimum Damage (%)	Maximum Damage (%)	Shift Factor
<2	3.4E+02	1.2E+05	0.000398
2-3	2.3E+02	3.2E+04	0.000524
2-4	5.0E+01	1.9E+04	0.002934
4-6	2.8E+01	3.2E+04	0.004
6-8	5.1E+00	2.7E+03	0.004
8-10	9.0E-01	1.3E+03	0.004
10-12	1.5E+00	4.3E+03	0.004
>12	5.6E-02	2.6E+02	0.004

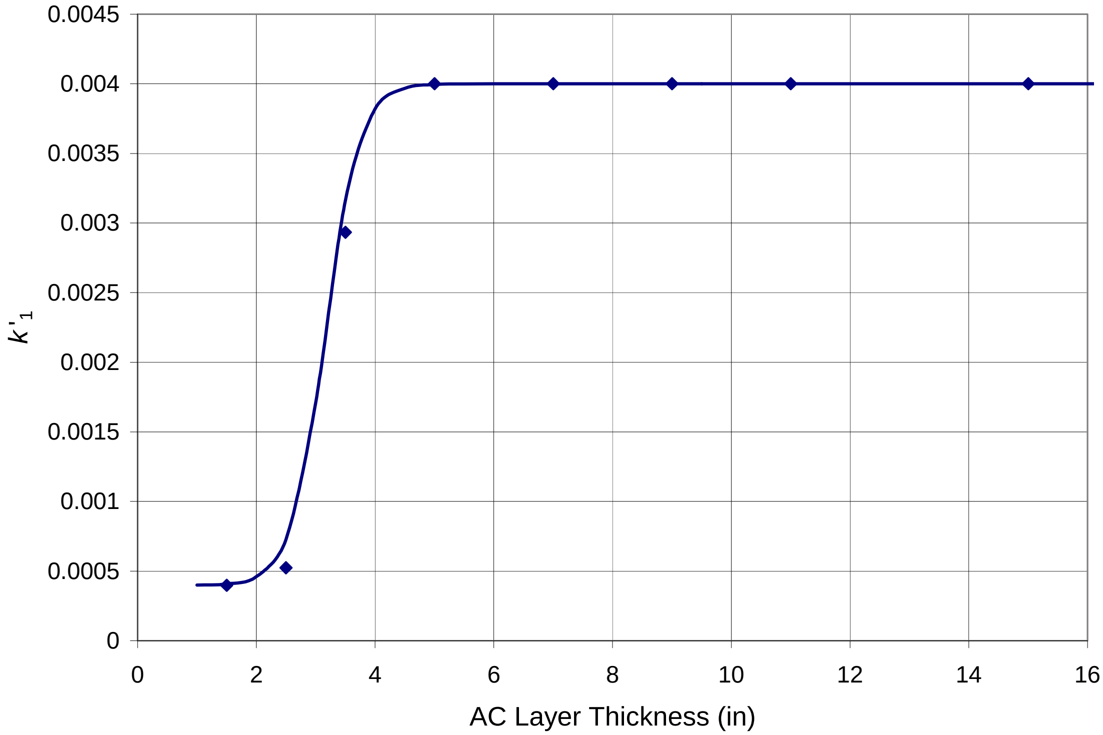


Figure 19 Sigmoidal Shift Function k'_1

Alligator Fatigue (Bottom-Up) Cracking Conclusion

The alligator fatigue (bottom up) cracking calibration process went through three main steps: estimation of coefficients β_{f2} and β_{f3} for the MS-1 number of load repetitions fatigue model; then finding the correlation between the alligator fatigue cracking and the damage using only sections with AC layer thickness greater than 4 inches; and finally shifting the thin sections using the "k'_1" parameter as a function of the AC layer thickness.

The final transfer function to calculate the fatigue cracking from the fatigue damage is based on the assumption that the fatigue cracking would be 50 % at a damage of 100 %. The calibrated model for the bottom-up fatigue cracking (% of total lane area) is expressed as follows:

$$F.C. = \left(\frac{6000}{1+e^{(C_1*C'_1+C_2*C'_2*\log10(D*100))}}\right)*\left(\frac{1}{60}\right) \tag{21}$$

where:

$C_1 = 1.0$

$C_2 = 1.0$

$C'_2 = -2.40874 - 39.748*(1+hac)^{-2.856}$

$C'_1 = -2 * C'_2$.

Number of observations	=	461 observations.
Sum of error square	=	17663.91
Standard error (S_e)	=	6.2 %.
S_e/S_y	=	0.947.

The bottom-up cracking is calculated as a percentage of the total lane area, based on the assumption that the lane is 500 ft long by 12 ft wide. It should be recalled that the measured cracking used in the calibration is the total summation of the high, medium and low severity cracking reported in the LTPP database. Figure 20 shows the graph of the calibration of the measured alligator cracking to the predicted bottom-up cracking, while Figure 21 shows the error (predicted – measured) in the prediction of the bottom-up fatigue cracking.

The 2002 Design Guide is based on mechanistic principles that provided a fundamental basis for the structural design of pavements structures. However, without calibration, the results of the mechanistic predictions cannot be confidently used to predict fatigue cracking with the confidence and assurance that it will model field behavior as accurately as possible. While the mathematical optimization techniques used in the error minimization approach are one form of field verification, an equally important component of the overall model verification is to insure that the final model developed provides extremely reasonable correlations to known impacts of significant variables in the fatigue process. In order to insure that this added verification effort did indeed occur, an extensive sensitivity analysis was run using different levels of key variable that are known to have an impact upon alligator (bottom-up) cracking. The results and discussions of this study are contained in Appendix II2. This sensitivity study contains a very detailed investigation as well as discussion of results for each major set of variables investigated.

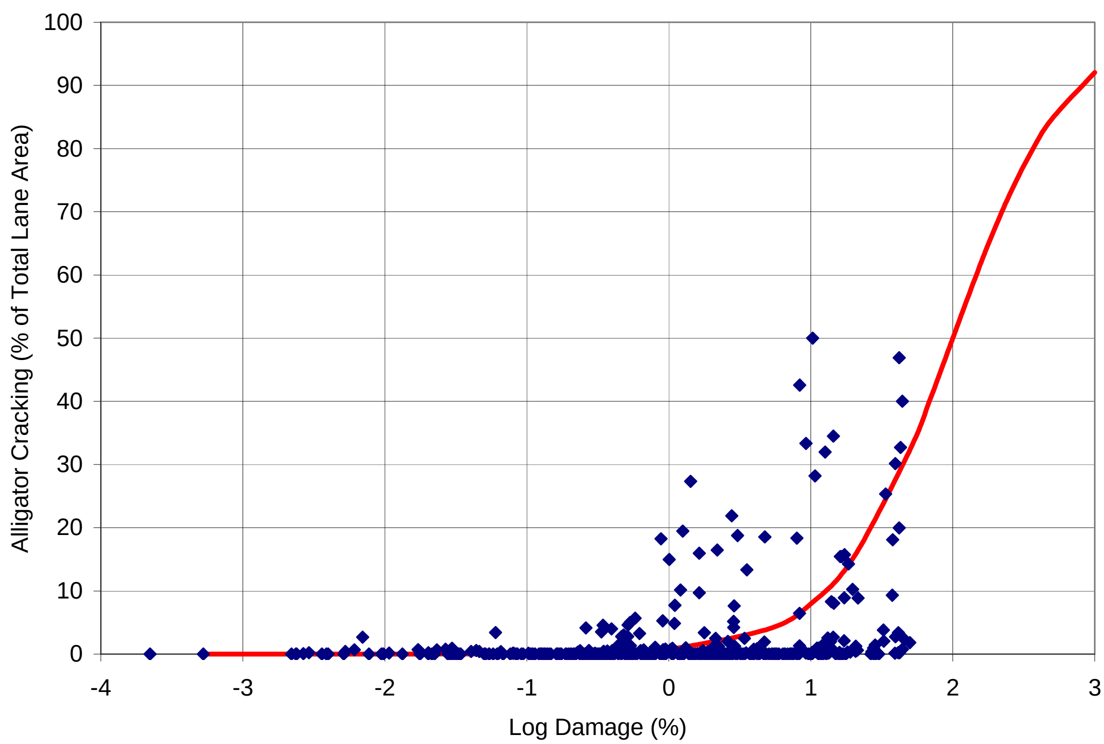


Figure 20 Bottom-Up Cracking vs. Fatigue Damage at Bottom of HMA layer

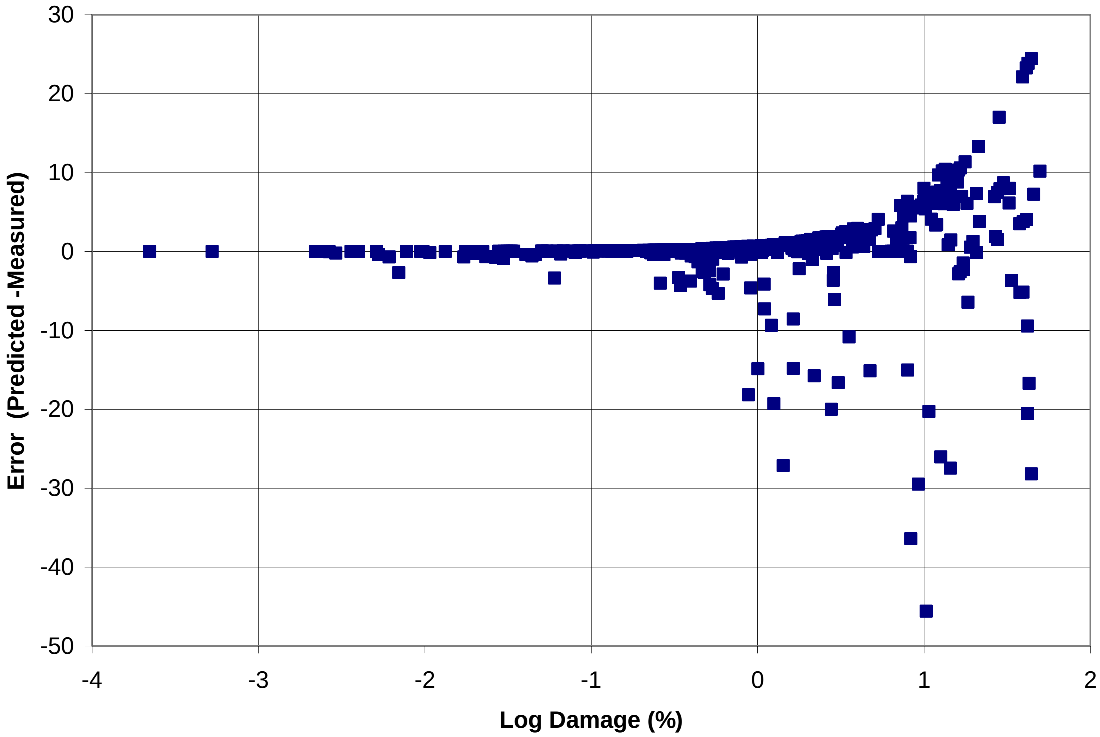


Figure 21 Error (Predicted – Measured Cracking) vs. Damage (%) for the Bottom-Up Fatigue Cracking.

Bottom-Up Fatigue Cracking Reliability

For reliability based design solutions; the predicted load associated fatigue cracking at the desired level of reliability is determined by:

$$FC\_P = \overline{FC} + S_{eFCi} * Z_P \tag{22}$$

where,

FC_*P* = predicted cracking at the reliability level P, %.
$\overline{FC}$ = predicted cracking based on mean inputs (corresponding to 50% reliability), %.
Se_{FCi} = standard error of estimate obtained from final field calibration
Z_P = standard normal deviate, dependant upon desired reliability level.

$$Se_{FCBottom} = 0.5+12/(1+e^{1.308-2.949*\log D}) \tag{23}$$

Figure 22 shows the plot of the measured standard error calculated from the data versus the cracking. The standard error equation was calculated based on dividing the predicted damage into groups based upon log damage intervals. The standard error within each interval was then calculated for each group. Table 8 summarizes the damage groups and the measured standard error. The final model fitted to the data is shown in equation 16. As shown in the figure, a sigmoidal function was used, as the standard deviation will reach a maximum value for very high damage percentages.

Table 8 Computed Statistical Parameters for Each Data Group (Alligator Cracking)

Group	Range of Predicted log(Damage(%))	Number of Data Points	Average Predicted log(Damage(%))	Standard Deviation of Measured Cracking, percent
1	< -2	18	0.502	0.682
2	-2 to -1	47	0.552	0.562
3	-1 to 0	161	1.281	1.811
4	0 to 1	158	6.494	6.225
5	> 1	77	11.563	12.049

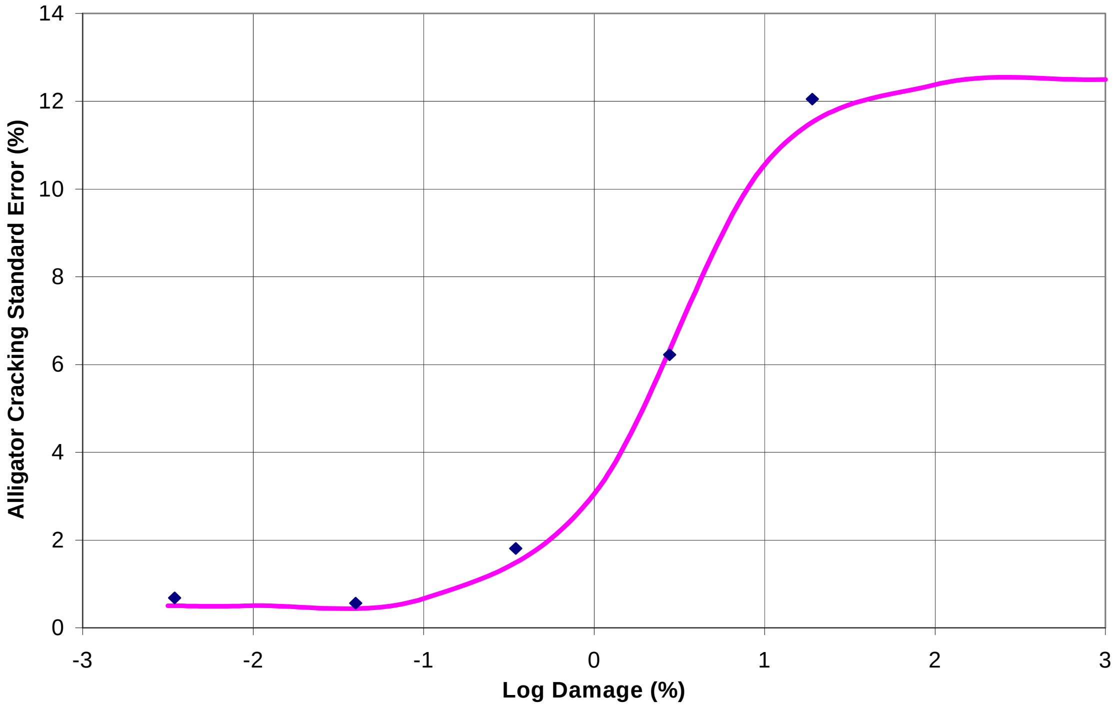


Figure 22 Standard Deviation of the Predicted Bottom-Up Cracking

Top-Down Fatigue Cracking Calibration

Similar to the bottom-up alligator fatigue cracking analysis, the ultimate goal of the top-down longitudinal surface cracking calibration is to find the transfer function, which will correlate predicted damage to measured cracking with the minimum amount of error. This section focuses on the top-down fatigue cracking distress. The final stage of the calibration, include the analysis of field cracking data to check the factors and trends of the longitudinal cracking measured in the field; model adjustment (development) of a shift function to correct for the constant strain (AC thickness effect) in the MS-1 fatigue-cracking model and finally optimizing the transfer function, to correlate the predicted damage to the measured longitudinal cracking with minimum error and maximum accuracy.

The top-down longitudinal cracking is a distress that starts at the surface of the pavement then propagates in the asphalt layer. As noted throughout this report, the mechanism hypothesized for this distress was due to excessive tensile strains at, or near, the pavement surface. At the beginning of the study, it was assumed that surface fatigue cracking could be a result of the combination of strains occurring at the surface of the pavement due to both environmental conditions (thermal) as well as load associated. In order to thoroughly investigate the feasibility of such a hypothesis, different combinations of the surface strains, were used in the prediction of the damage for longitudinal (top-down) cracking.

Different scenarios were tested for the prediction of the surface – down cracking. These scenarios were different in the way the surface strains were obtained. Tensile strains that occur at the surface due to traffic loads were always included. However, the strains induced from thermal changes in cooler climatic zones were initially investigated in the calibration study. Several scenarios using combined thermal and load strains were investigated. These scenarios included use of the maximum tensile strains in an analysis period or using the average thermally induced strains. Another approach also investigated was to totally ignore the temperature induced strains.

Another important initial consideration was evaluated due to the fact that the longitudinal cracking mechanism is not very well understood (compared to the alligator cracking). In the initial study phases, the strains for the longitudinal cracking were calculated at two different depths: at the surface and at 0.5” below the surface. The logic in determining tensile strains at the 0.5” depth was to assess if the aged hardened upper 1” AC layer was being “fatigued” due to the aging phenomenon. All of these scenarios were evaluated in an attempt to better understand how the longitudinal cracking develops and how it should be correctly modeled.

Once the final tensile strain scenario for the longitudinal cracking was selected, the calibration process followed similar steps as the calibration process of the alligator (bottom-up) fatigue cracking. In the following sections, the different scenarios for the longitudinal fatigue cracking will be discussed and the calibration process will be explained. The discussion will start with the analysis of some trends of longitudinal cracking from the LTPP database.

Analysis of Measured Longitudinal Cracking Data

The general approach used for the calibration of top-down fatigue cracking was conceptually identical to the approach used for the bottom-up alligator cracking. The database from the LTPP (12) was used to calibrate the distress models, and to compare field data trends to the calibration results trends to guide the calibration process. All data was extracted from the LTPP database provided in the DataPave (version 3) software.

Longitudinal fatigue cracking data was collected from all available new LTPP sections indicating the presence of longitudinal cracking. The total number of sections used was 640 sections. Each section had a multiple data point as a time series. The total number of time- distress –sections points used was 1897. The LTPP database provided the longitudinal cracking data according to severity level (low, medium and high severity) for each LTPP section. The LTPP sections have a length of 500 feet. In this research work, as mentioned earlier, it was decided by the NCHRP panel overviewing this study, that the three fatigue cracking severity values would be added arithmetically, without any weighting coefficients, and used as the total fatigue cracking. A factor of 10.56 was then used to convert the longitudinal cracking from feet per 500 feet into feet per mile. It is to be noted that the prediction of the longitudinal surface fatigue cracking is a lineal measure, in contrast to the areal measure, used for the bottom-up alligator cracking.

At the same time, the thickness of all asphalt concrete layers, for each section, was extracted from the database. The thickness was then added to get the total thickness of asphalt concrete layers for each section. Figure 23 shows the frequency distribution of the longitudinal cracking. About 95% of the data points found in the database have longitudinal cracking less than 500 ft/mile. There are several hypothesized reasons for this limit. First, it is because the roadways are maintained if the distress reaches a certain level of cracking. Additionally it is logical that after a certain level of longitudinal cracking, the longitudinal cracking may become interconnected and become integrated into alligator cracking. Finally it should be recalled that a time series of distress was used in the database. Thus a majority of points will be in the early stages of distress, which will alter the apparent conclusions.

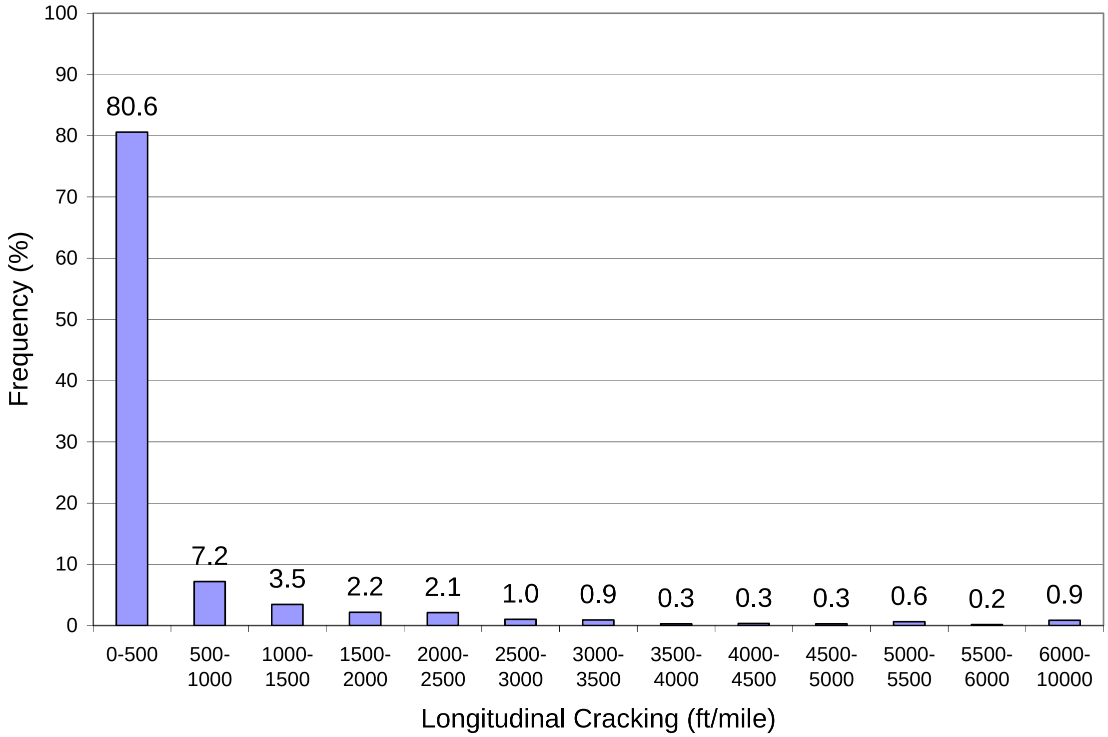


Figure 23 Frequency Distribution of Longitudinal Cracking

Figure 24 shows the plot of the total longitudinal cracking, from the 640 sections, to the total asphalt thickness. Figure 24 also shows that the longitudinal cracking in 640 sections at different asphalt thickness peaks at an asphalt layer thickness of 4 – 7 inches. Also, the figure shows that for thick asphalt layers, the longitudinal cracking definitely decreased. This provides some credulence to the consideration that the longitudinal cracking is, indeed, related to some structural properties of the pavement system. The same sections used for the alligator cracking were used in the longitudinal cracking. This is why the frequency of the total asphalt layer thickness is the same as shown in Figure 13. Quite candidly, the trends showing a decrease in longitudinal cracking, as the AC thickness increased, was opposite to initial views of the research team for longitudinal cracking. It was thought that more longitudinal cracking would occur with thick asphalt sections and less with thin sections. Obviously this was an erroneous initial impression.

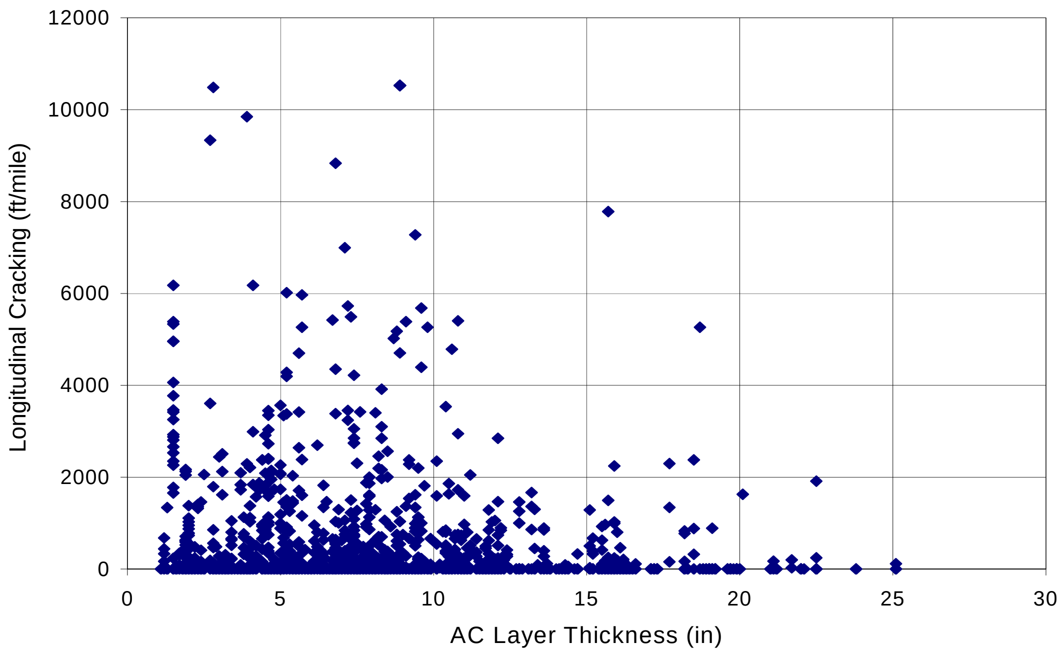


Figure 24 LTPP Longitudinal Cracking Data vs. Asphalt Layer Thickness

Another major factor that was investigated was the effect of the mean annual air temperature (MAAT) upon longitudinal cracking. As shown in Figure 25 and Figure 26, the MAAT ranges from about 29 ºF to about 77 ºF. Initially, it was the general expectation of research team that the longitudinal cracking would be more prevalent in cold regions, with less cracking in hot regions. However, the figures show that the longitudinal cracking appears to reach a maximum value at a MAAT near 60 to 70 ºF. When the MAAT was greater than 70 ºF or less than 50 ºF, the average longitudinal cracking decreased.

Another factor, which appears to have an impact on the longitudinal cracking, is the subgrade soil type. Figure 27 shows that more longitudinal cracking is observed in the field for stronger (sandy) subgrade soils. This finding lends some credulence to the final distress methodology developed in that stronger (higher) moduli foundations will tend to cause higher surfacial tensile strains in the pavement systems. This in turn, should result in a greater degree of surface cracking to occur.

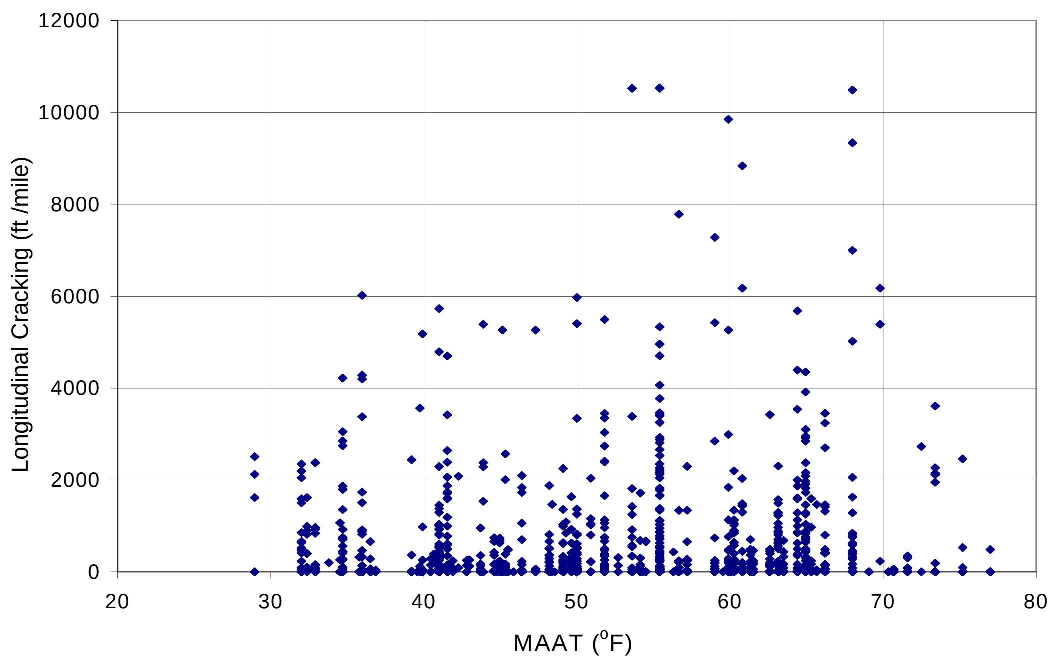


Figure 25 Longitudinal Cracking vs. Mean Annual Air Temperature

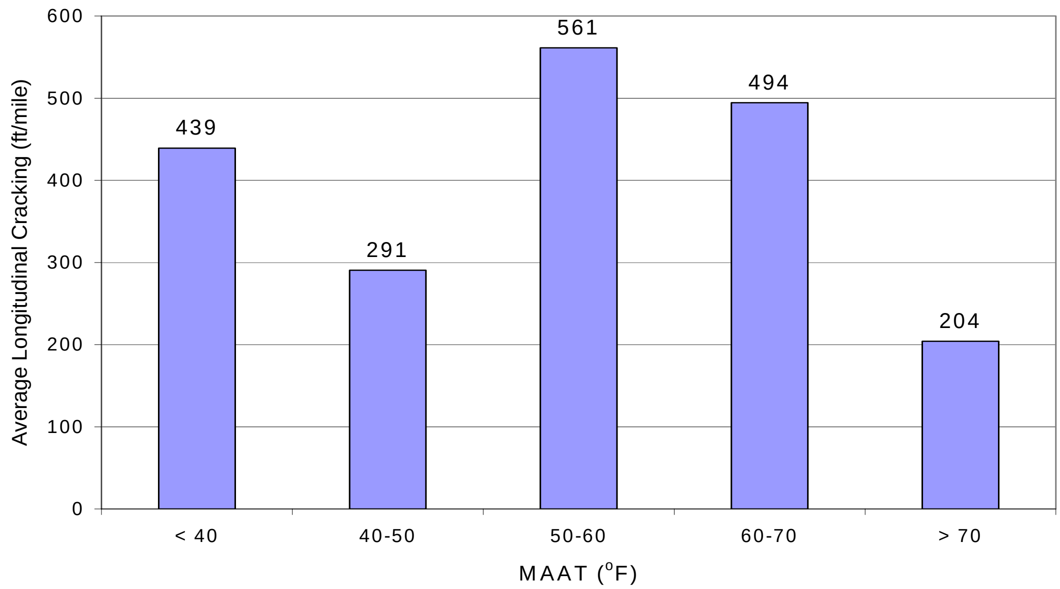


Figure 26 Average Longitudinal Cracking vs. Mean Annual Air Temperature Ranges

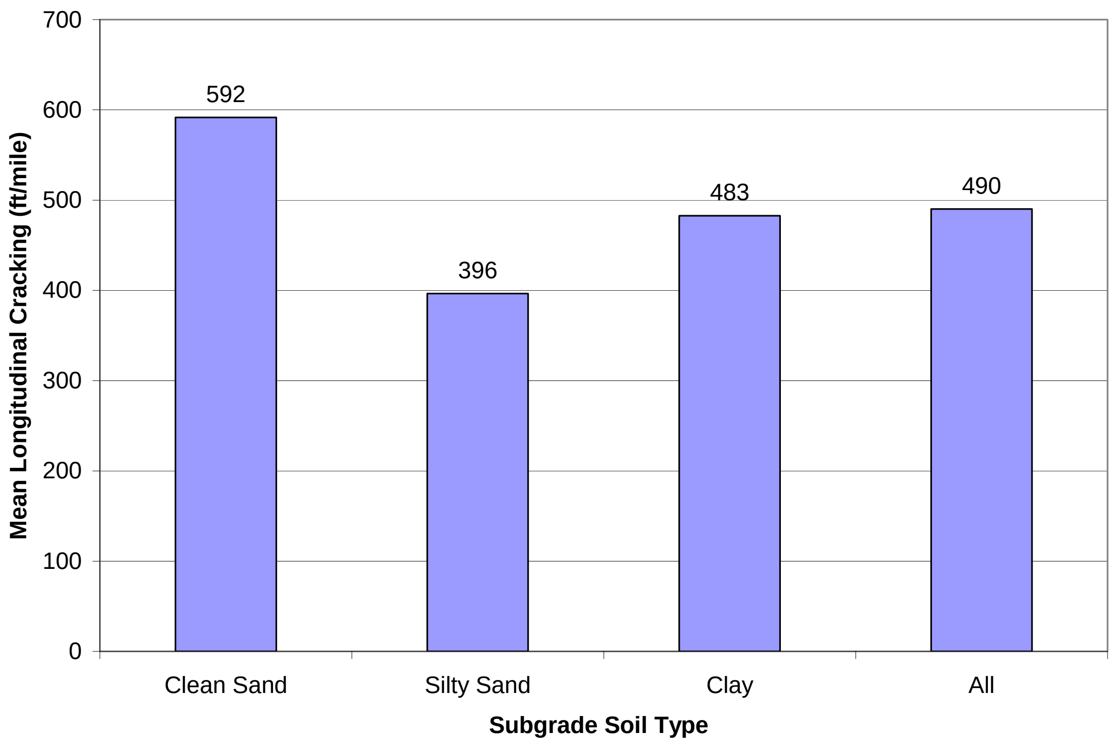


Figure 27 Average Longitudinal Cracking vs. Subgrade Soil type

Calibration of the Fatigue Longitudinal Cracking Model

The calibration process goal for the longitudinal cracking is to find the shift function for asphalt thickness and then to find the sigmoidal function relating the damage and the cracking. The following section will discuss these two steps using only the MS-1 model. The general MS-1 model is given in the following equation:

$$N_f = 0.00432 * C * \beta_{f1} \left(\frac{1}{\varepsilon_t} \right)^{3.291*\beta_{f2}} \left(\frac{1}{E} \right)^{0.854*\beta_{f3}} \tag{24}$$

It has to be noted that the same fatigue model (MS-1) was selected to be used for the damage prediction of both the top-down and bottom-up procedures. In fact, the decision to use the MS-1 and not the Shell Oil model was taken based on the results obtained from the bottom-up cracking. Since the fatigue damage is being calculated for distress types (longitudinal and alligator cracking) the same model should be used.

Similar to the alligator cracking, there are three calibration factors (β_{f1}, β_{f2} and β_{f3}) that need to be evaluated. β_{f1} would be a function of the AC layers thickness. In addition to the estimation of these three alligator fatigue cracking calibration factors, a transfer function between the predicted damage and measured cracking is required to complete the calibration process.

The tensile strains, which are used to calculate the longitudinal cracking, were calculated at two depths, at the surface and at 0.5 inch below the pavement surface. However, in 100% of every analysis conducted in the entire study, tensile strains at the surface were much higher (more critical) than those strains calculated at 0.5" deep. This finding appears to suggest that long-term aging of the upper thin AC layer does not play a significant role in the longitudinal surface cracking process. Accordingly, it was decided to only use tensile strains at the surface (Z = 0) for the longitudinal cracking calibration process. The tensile strains for the damage prediction were calculated at different horizontal (x – y) locations as explained in and earlier section. The maximum tensile strain at the 10 locations is used in the analysis. In the majority of cases evaluated, the maximum location was found between the dual tires and at the AC surface.

The fatigue cracking – damage transfer function used in the calibration of the Design Guide for longitudinal (surface-down) fatigue cracking is in the form shown in equation 25.

$$F.C. = \left(\frac{1000}{1 + e^{C_1 - C_2 * LogD}} \right) * (10.56) \tag{25}$$

where:

$F.C.$ = fatigue cracking (ft / mile)
D = Damage in percentage

C_1, C_2 = regression coefficients

The “1000” is the maximum length of linear cracking which can occur in two wheel paths of a 500 feet section (2 * 500 feet length). The (10.56) factor is a conversion to feet per mile units.

The regression coefficients C_1 and C_2 were evaluated using a Microsoft Solver numerical optimization routine. The optimization was set by first predicting the surface damage using the MS-1 model. An initial value was assumed for C_1 and C_2. Then by using the equation form given in equation 25, fatigue cracking was calculated from the predicted damage percentage. The predicted longitudinal fatigue cracking was then compared to the measured cracking. The Microsoft Excel Solver was then run to minimize the sum of squared errors by changing the C_1 and C_2 values for the first iteration. The new C_1 and C_2 values are then used as the input for the second iteration, and the same steps repeated until the solution converges and the minimum total sum of squared errors is obtained. Finally, the Microsoft Solver is used again to set the arithmetic sum of errors to zero (by changing the C_1 and C_2 values again). This is done in order to eliminate any bias in the prediction. The same assumption assumed for the alligator cracking was assumed for the longitudinal cracking; in that the cracking would be 50% at a damage of 100%.

The longitudinal fatigue cracking calibration process can be summarized in the following steps:

1. Estimation of β_{f2} and β_{f3}
2. Finding β_{f1} as a function of the AC layers thickness.
3. Finally, the longitudinal fatigue cracking – damage transfer function is optimized by minimizing the error to get a final value of C_1 and C_2.

For the longitudinal surface cracking fatigue subsystem, there was an interaction between step 2 (finding β_{f1}) and step 3 (finding the longitudinal cracking transfer function). This is in contrast to the alligator cracking, for which the two steps were independent and completed separately. That is why, step 2 and 3 for the longitudinal cracking calibration was repeated by trial and error to find the minimum error.

In the following sections, a step-by-step solution of the longitudinal (surface) cracking calibration process is presented.

Estimation of β_{f2} and β_{f3}

For the longitudinal cracking, the MS-1 fatigue model was selected to be consistent with the bottom-up fatigue cracking predictions. Also, the lack of a well-founded and accepted distress methodology for the longitudinal cracking mechanism led to the assumption to use the same model and calibration coefficients as the alligator bottom-up cracking. Accordingly the same values were used for the calibration coefficients β_{f2} and β_{f3}. The calibration factors β_{f2} and β_{f3} were set at 1.2 and 1.5 respectively. The MS-1 model used for the longitudinal cracking calibration process is as follows:

$$\beta_{f1} = \beta'_{f1} * k_1'$$
$$\beta_{f2} = 1.2$$
$$\beta_{f3} = 1.5$$
$$N_f = 0.00432 * \beta'_{f1} * k_1' * C \left(\frac{1}{\varepsilon_t}\right)^{3.9492} \left(\frac{1}{E}\right)^{1.281} \tag{26}$$

where:

β'_{f1} = Numeric value

k_1' = Function of the AC layer thickness

Longitudinal Damage Tensile Strains

As mentioned earlier, the initial surface (top-down) fatigue study utilized different combinations of load-associated strains and low temperature-induced strains to predict the damage for the longitudinal cracking. The load-associated strains are the strains that were produced from the effect of the traffic load. Low temperature (thermal) strains are the strains induced in the pavement, especially near the surface, due to quick temperature drops that lead to thermal induced stresses and strains due to the frictional restraint of the pavement and the relaxation and tensile properties of the AC surface mix. The thermal strains are generally of consequence in relatively cool temperature periods and increase as the temperature becomes well below freezing. In a pavement system, the primary mode of stress – strain development is parallel to the long axis of the road. In other words, thermal strains due to temperature drops are only of a practical consequence in the direction of travel.

In contrast, load-associated horizontal tensile strains are calculated in two directions: the traffic direction and perpendicular to the traffic direction. However, the temperature strains are calculated in only one direction, which is the direction perpendicular to the traffic. In the investigation to assess if thermal strains needed to be incorporated in the fatigue model, thermal tensile strains were added to the load strains parallel to traffic, and then the summed value compared to the load strains in the direction perpendicular to traffic. The most critical strain of the two was used for the damage calculation in the preliminary study.

The incremental prediction period for the damage calculation is two weeks when freezing and thawing exists and one month if no freezing / thawing is present. However, the temperature measurement provided in the Design Guide is an hourly temperature. This is required input format for the solution of the thermal fracture module for asphalt pavement system. In order, to use the predicted thermal strains for the longitudinal cracking prediction, direct use of the thermal fracture subsystem was used.

The specific combinations investigated were:

1. Load associated strains plus the average thermal tensile strain within the analysis period.
2. Load associated strains plus the maximum thermal tensile strain within the analysis period.
3. Load associated strains only.

All of these combinations were evaluated using the calibration factors of 1.2 and 1.5 for the β_{f2} and β_{f3}. A complete calibration was conducted on each of these three combinations to assess the accuracy of the prediction model by comparing the standard error for each calibration. Figure 28, Figure 29 and Figure 30 show the plots of the predicted damage versus the measured longitudinal cracking for the three tensile strains combinations respectively. The standard error for each calibration process is shown in Table 9.

From Table 9 it is clear that only using the load associated tensile strains provides the least standard error (1242.25 ft / mile) and the lowest Se/Sy (1.388). The use of adding either the average or the maximum thermal tensile strain to the load associated strains, yields a very close standard error for both combinations (2113.4 and 2028.6 respectively). However, these values are much higher than the load associated tensile strains alone.

The results of this initial study allowed one to clearly conclude that the best methodology with the least error was the one in which only the load-associated strains were used. Adding the temperature strains introduced a larger degree of variability and scatter in the predicted values, leading to very high errors.

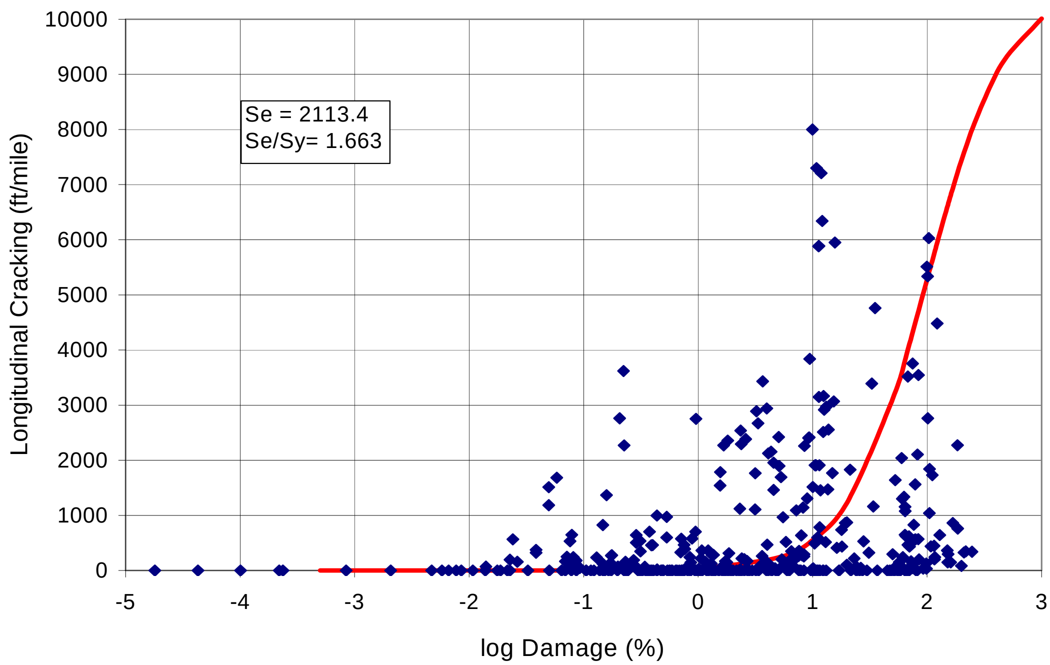


Figure 28 Longitudinal Cracking vs. Damage Using Load Associated and Average Thermal Tensile Strains

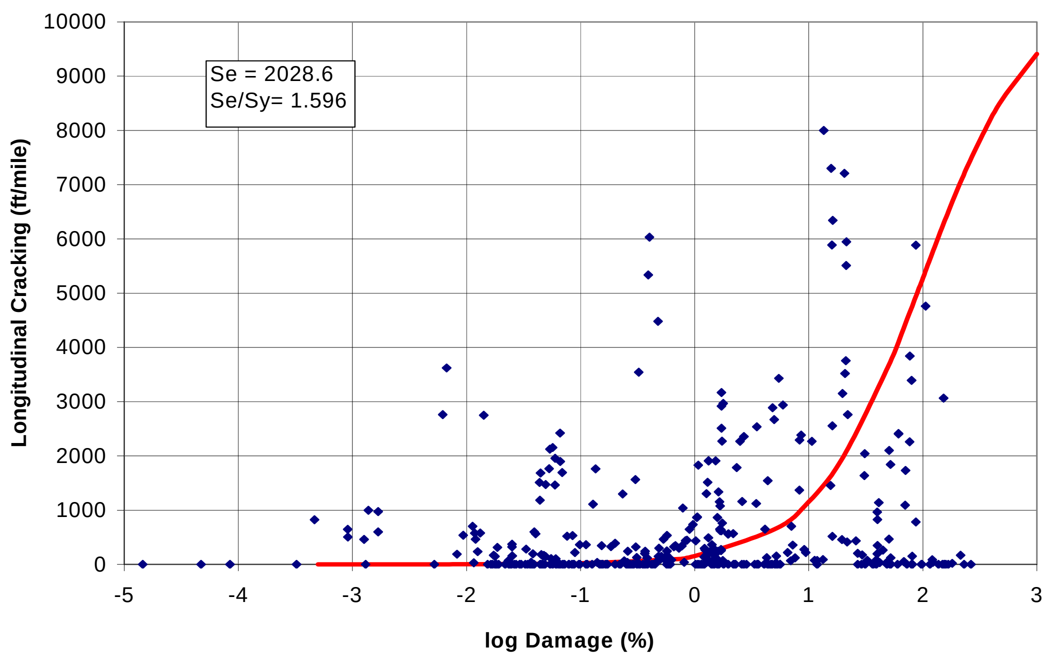


Figure 29 Longitudinal Cracking vs. Damage Using Load Associated and Maximum Thermal Tensile Strains

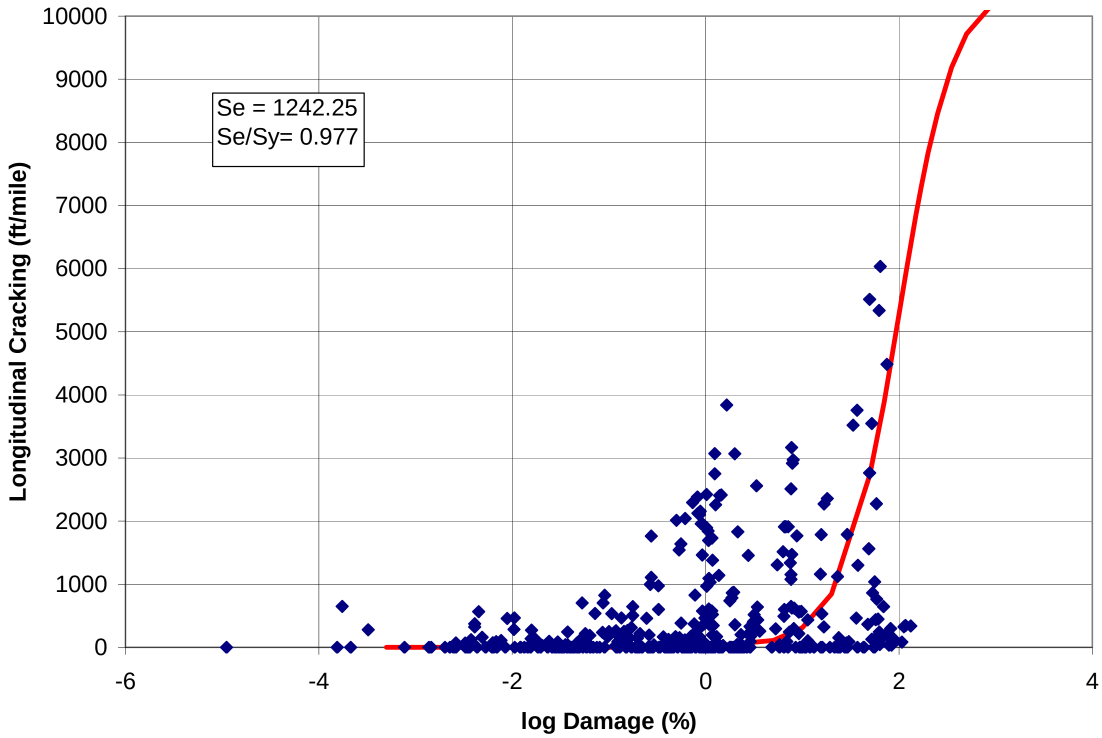


Figure 30 Longitudinal Cracking vs. Damage Using Load Associated Tensile Strains

Table 9 Standard Error For Load and Temperature Tensile Strains Combinations.

Tensile Strain Combination	Standard Error (Feet/mile)	Se/Sy
Load Associated +Average Temperature Tensile Strains	2113.4	1.663
Load Associated +Maximum Temperature Tensile Strains	2028.6	1.596
Load Associated Tensile Strains Only	1242.25	0.977

Estimation of $k_1^{'}$ Function and C_1/ C_2 values

Using only the tensile strains associated with the applied traffic, the final stage of the calibration was to find the transfer function between the longitudinal cracking and the damage. However, before getting into that stage a check was done on the distribution of the measured cracking versus the thickness of the AC layers.

A transfer function was optimized using the Microsoft Solver to find the values of C_1 and C_2 from equation 25 without doing any shift or correction for the AC layer thickness. Figure 31 shows a bar chart of the average longitudinal cracking versus the AC layer thickness. Figure 31 shows that if the cracking was done without any thickness shift (using the original form of the equation and setting the "$k_1^{'}$" factor to 1) the top-down cracking prediction would be higher for thinner sections and will decrease as the asphalt layer thickness increase. This contrasts the findings described in an earlier section, which clearly showed that the longitudinal cracking peaks at an AC thickness of 4-7 inches and that it significantly decreases outside this range.

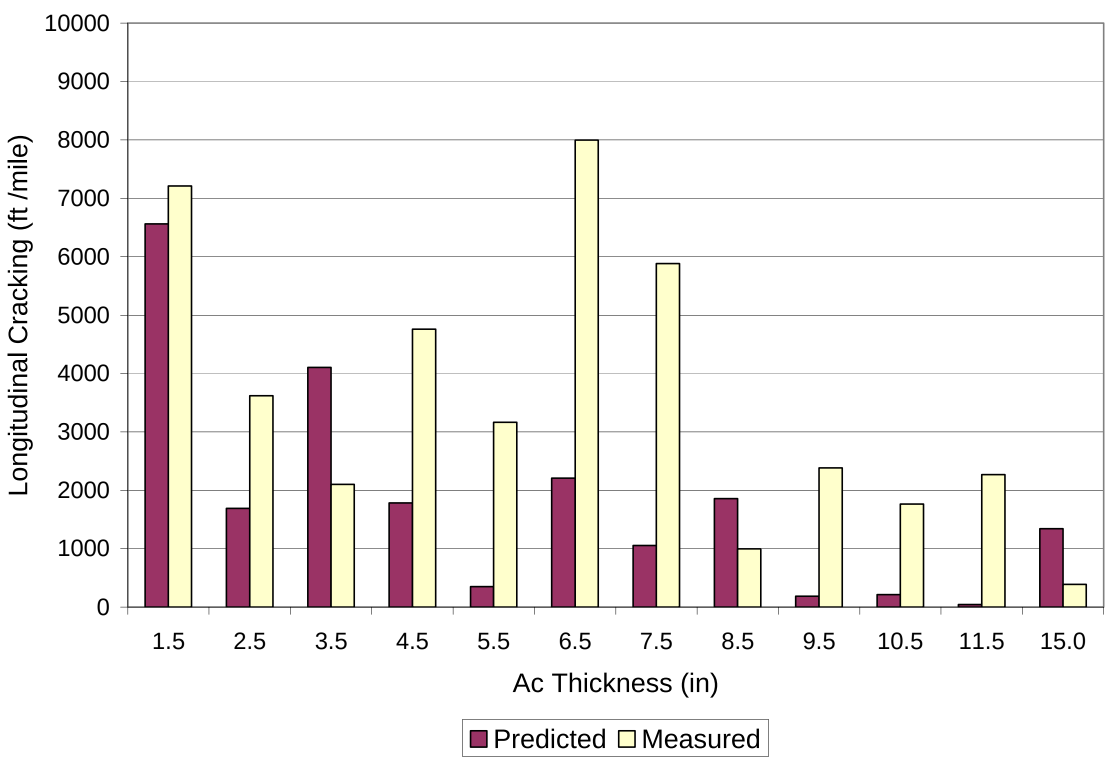


Figure 31 Measured and Predicted Longitudinal Cracking vs. Asphalt Concrete Thickness without using Thickness Shift Factor

These finding imply the necessity to develop a thickness shift function. The data was subdivided into groups by the AC thickness as shown in Table 10. For each AC thickness group a factor was estimated to shift the predicted cracking to match the measured. This shift factor was developed manually. Using these results, a sigmoidal function was then fitted for the shift values. Microsoft Excel Solver was used to minimize the error. However, in this comparison the predicted longitudinal cracking needed to be calculated, in order to compare it to the measured longitudinal cracking. This required the solution of equation 25 to obtain a value for C1 and C2. An iterative process was used, in which the $k_1^{'}$ was found first for an assumed C_1 and C_2. C_1 and C_2 were then optimized. Then the new C_1 and C_2 were used to find a new $k_1^{'}$, and so on until the solution converged.

However, Figure 32 shows that after introducing the thickness shift function, the corrected predictions compared with the measured values much better. Also, Figure 33 shows the plot of the shift function obtained for the longitudinal cracking. For the longitudinal fatigue (top down) cracking the "$k_1^{'}$" parameter developed resulted in the following equation:

$$k'_1 = \frac{1}{0.0001 + \dfrac{29.844}{1 + e^{(30.544 - 5.7357 * hac)}}} \tag{27}$$

where:

h_{ac} = Total thickness of the asphalt concrete layers

Table 10 Longitudinal Cracking AC Thickness Shift Factors

AC Layer Thickness	Shift Factor
<2	0.01
2,3	0.10
3,4	1.50
4,6	2.00
6,8	12.00
8,10	12.00
10,12	12.00

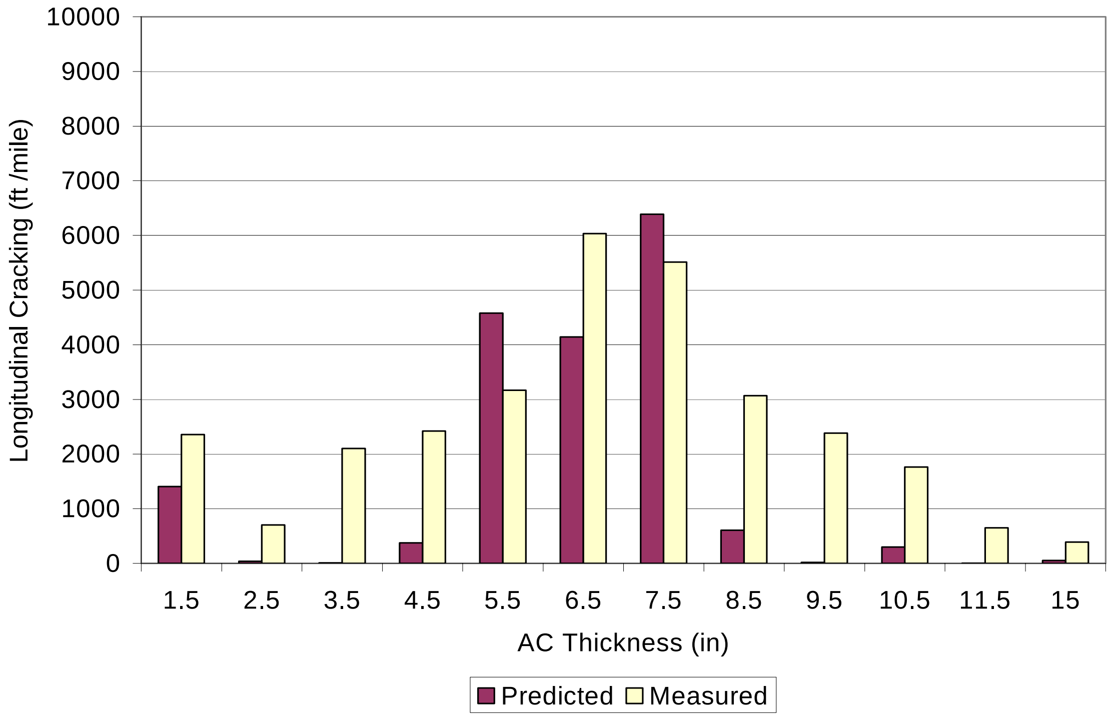


Figure 32 Measured and Predicted Longitudinal Cracking vs. Asphalt Concrete Thickness using Thickness Shift Factor

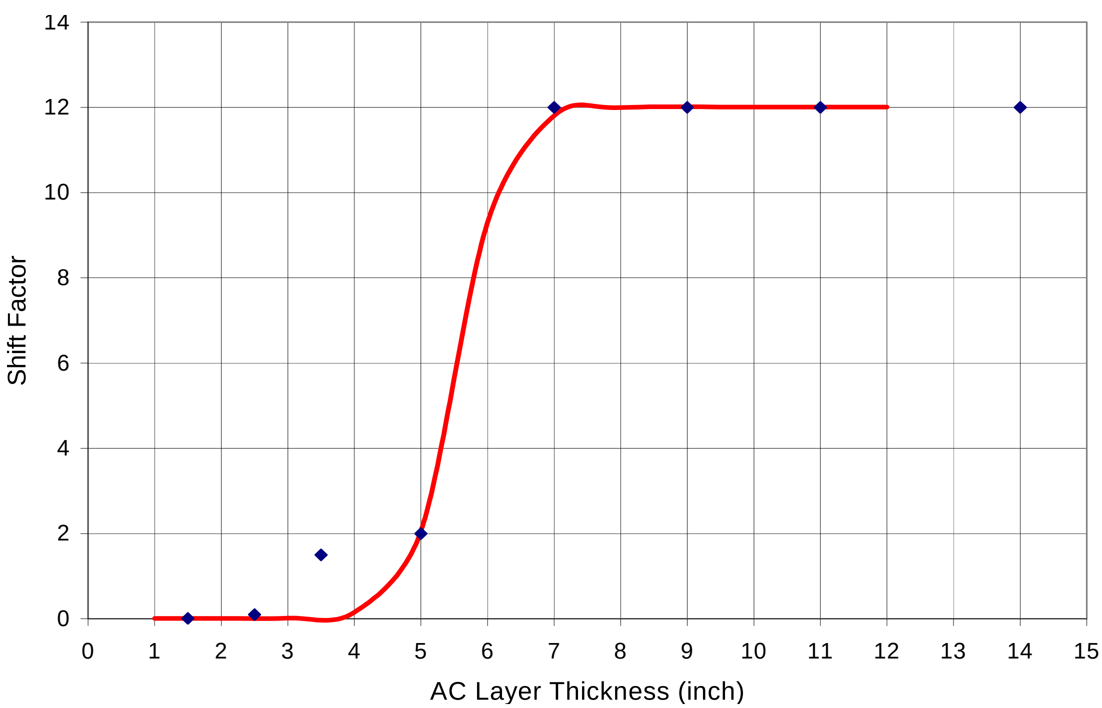


Figure 33 Longitudinal Cracking Shift Function

The final transfer function to correlate the longitudinal fatigue cracking from the fatigue damage is based on the assumption that the longitudinal surface fatigue cracking would be 5000 ft /mile at a damage of 100 %. The calibrated model is expressed as following:

For the top-down cracking (feet/mile)

$$F.C. = \left(\frac{1000}{1 + e^{(7 - 3.5 * \log 10(D * 100))}} \right) * 10.56 \tag{28}$$

Number of observations	=	414 observations.
Sum of error square	=	6.37e8
Standard error (S_e)	=	1242.25 ft/mile.
S_e/S_y	=	0.977.

The top-down cracking is calculated as linear feet in the wheel path. The measured cracking used in the calibration is the unweighted sum of the high, medium and low severity cracking reported in the LTPP database. Figure 30 (previously shown) indicates the final calibration model of the measured to predicted top-down longitudinal cracking. Figure 34 shows the error (predicted – measured) in the prediction of the top-down fatigue cracking.

To ensure that the calibrated model is as accurate as possible and that the predicted model trends are as close as possible to what experience, practical knowledge and reasonable engineering judgment of the performance of the asphalt concrete pavements allows; an extensive sensitivity analysis was conducted using a wide variety of salient variables that were felt to have an impact on top-down fatigue cracking. The results of the sensitivity analysis for the top-down fatigue cracking are given in Appendix II3. This appendix contains an in-depth detailed analysis for the entire sensitivity study.

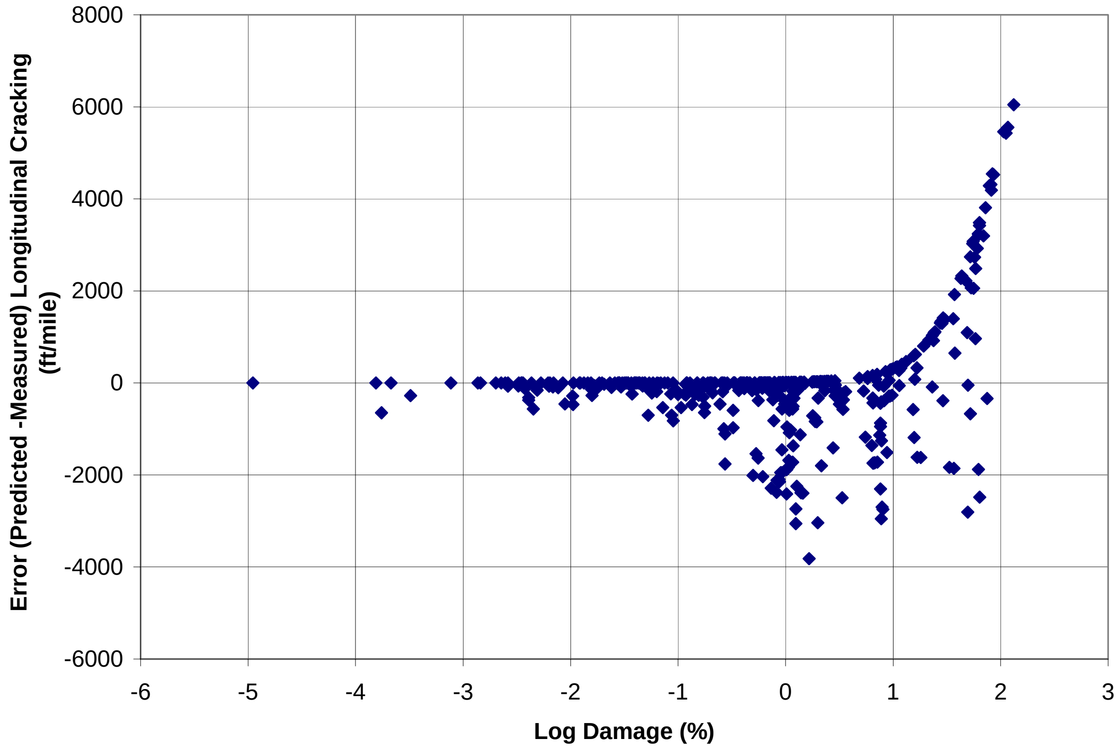


Figure 34 Error (Predicted – Measured Cracking) vs. Damage (%) for Top-Down Fatigue Cracking.

Top-Down Fatigue Cracking Reliability

The reliability design is obtained by determining the predicted load associated fatigue cracking at the desired level of reliability as follows:

$$FC\_P = \overline{FC} + S_{eFCi} * Z_P \tag{29}$$

where,

FC_*P* = predicted cracking at the reliability level P, ft/mile.
$\overline{FC}$ = predicted cracking based on mean inputs (corresponding to 50% reliability), ft/mile.
Se_{FCi} = standard error of cracking at the predicted level of mean cracking
Z_P = standard normal deviate, based upon desired reliability level.

$$STD_{FCTop} = 200+2300/(1+e^{1.072-2.1654*\log D}) \tag{30}$$

Figure 35 shows the plot of the measured standard deviation calculated from the data versus the cracking damage. The final model fitted to the data is shown in equation 30. As seen, a sigmoidal function is used, as the standard deviation will reach a maximum value for very high damage percentages. The standard error equation was calculated based on dividing the predicted damage into groups, then calculating the standard error for each group. Table 11 shows damage groups and the measured standard error.

Table 11 Computed Statistical Parameters for Each Data Group (Longitudinal Cracking).

Group	Range of Predicted log(Damage(%))	Number of Data Points	Average Predicted log(Damage(%))	Standard Error for Predicted Longitudinal Cracking, ft/mi
1	< -2	33	-2.655	204.8
2	-2 to -1	69	-1.476	200.2
3	-1 to 0	118	-0.413	702.9
4	0 to 1	125	0.428	1104.7
5	> 1	69	1.561	2497.5

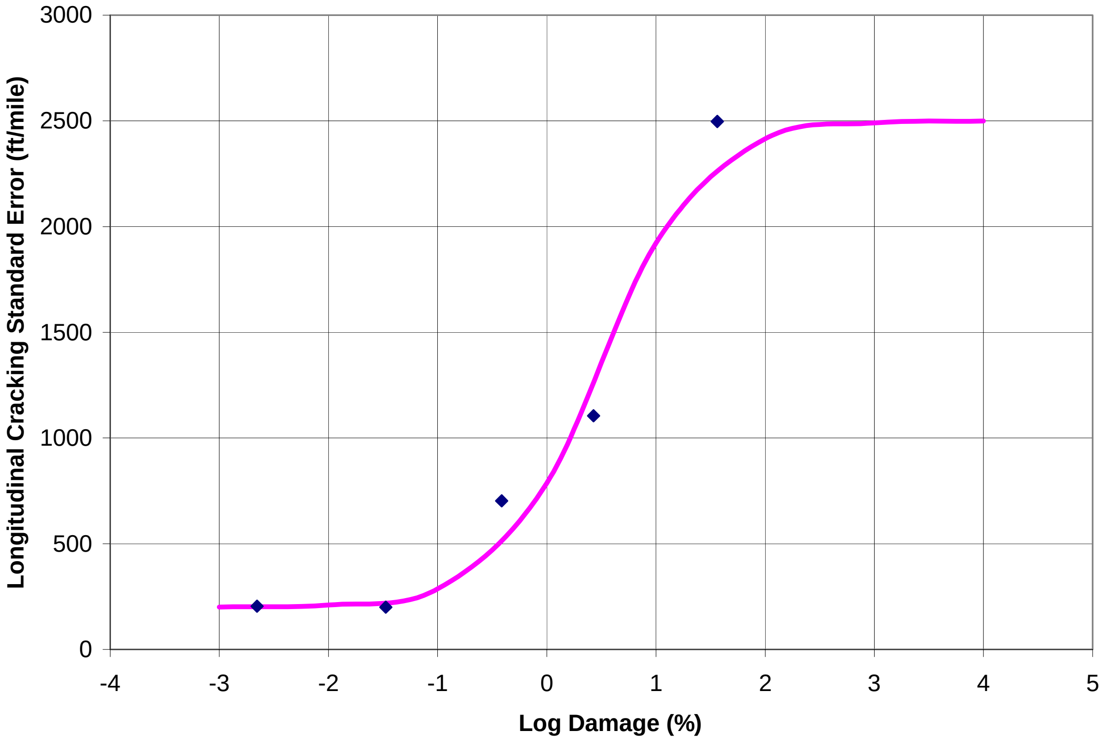


Figure 35 Standard Deviation of the Predicted Top-Down Cracking

Fatigue Cracking Calibration Conclusions

Two distinct types of fatigue cracking phenomena were considered. The first was the classical bottom-up cracking; which was assumed to be related to conventional alligator cracking. The alligator cracking was reported as a percentage of the total pavement area exhibiting alligator cracking. The total pavement area was defined by a 12-foot wide lane width by 500-foot long sections (geometric dimensions from LTPP database). This maximum percent alligator cracking is associated with an area of 6000 ft^2. Alligator fatigue cracking is assumed to be initiated from horizontal tensile strains occurring at the bottom of the asphalt layers.

The second type of fatigue cracking was the surface (top-down) cracking. This distress was related to the longitudinal cracking in the pavement system. This fatigue distress type is characterized as the magnitude of longitudinal cracking in feet per mile. LTPP distresses, used in the calibration effort, were adjusted from the 500-foot LTPP section length, to reflect distress reported on a per mile basis of road length. The mechanism that was eventually selected to provide the best agreement to field observations, was a fatigue model related to the tensile strain occurring at the surface of the asphalt layer system. Maximum tensile strain values (and hence fatigue damage) were found to be always associated with the surface tensile strains between the set of dual wheels within a single, tandem, tridem or quad gear configuration.

Based upon the fatigue calibration study, it can be summarized that:

- The fatigue cracking calculations were based on using Miner's law for cumulative damage.

$$D = \sum_{i=1}^{T} \frac{n_i}{N_i}$$

- The general basic form of the fatigue damage prediction model was initially defined by:

$$N_f = k_1 \left(\frac{1}{\varepsilon_t} \right)^{k_2} \left(\frac{1}{E} \right)^{k_3}$$

- The final Design Guide methodology incorporated two types of fatigue cracking prediction models based on the thickness of the AC layer: constant stress fatigue conditions were assumed to be applicable with thick AC sections while constant strain principles were adopted for thin sections.
- For the fatigue cracking distress, two existing AC models were initially considered as viable potential candidates in the calibration: the Shell Oil model and the Asphalt Institute (MS-1) model.

- The Shell Oil (6) model contains two separate fatigue relationships: one for the constant stress conditions (thick sections greater than 8 inches) and another for constant strain conditions (thin sections less than 2 inches). These equations are:

<u>Constant Strain</u>

$$N_f = A_f[0.17PI - 0.0085PI(V_b) + 0.0454V_b - 0.112]^5 \varepsilon_t^{-5} E^{-1.8}$$

<u>Constant Stress</u>

$$N_f = A_f[0.0252PI - 0.00126PI(V_b) + 0.00673V_b - 0.0167]^5 \varepsilon_t^{-5} E^{-1.4}$$

- A general model representing the Shell Oil was developed by fitting a sigmoidal function between the two models to transition asphalt thicknesses between 2 – 8 inches. The final fatigue model for Shell Oil that was used in the original calibration effort is given by:

$$N_f = A_f \left(1 + \frac{13909E^{-0.4} - 1}{1 + \exp^{(1.354h_{ac} - 5.408)}}\right)(0.0252PI - 0.00126PI(V_b) + 0.00673V_b - 0.0167)^5 \left(\frac{1}{\varepsilon_t}\right)^5 \left(\frac{1}{E^*}\right)^{-1.4}$$

where

$$F" = 1 + \frac{13909E^{-0.4} - 1}{1 + \exp^{(1.354h_{ac} - 5.408)}}$$

$$K_{1\alpha} = [0.0252PI - 0.00126PI(V_b) + 0.00673V_b - 0.0167]^5$$

A_f = laboratory to field adjustment factor (default = 1.0)

- The second existing model used in the calibration evaluation was the Asphalt Institute MS-1 fatigue model. It is defined by:

$$N_f = 0.00432C\left(\frac{1}{\varepsilon_t}\right)^{3.291}\left(\frac{1}{E}\right)^{0.854}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

- In the actual fatigue calibration work, 82 sections out of the 94 sections collected for this study, had fatigue data. The quantification of the fatigue distress was as follows.

- The cracking (alligator and longitudinal) reported in the LTPP database is reported based on the severity level (low, medium and high). According to the panel supervising this project, it was recommended to use the arithmetic summation of the three levels without applying any weighing factor. This was followed by the research team, for both types of fatigue cracking.

- Alligator cracking was reported as percentage of the total pavement area (12 feet width by 500 feet length = 6000 ft^2). While the longitudinal cracking was reported as the total longitudinal cracking in feet per mile.

- For the bottom-up cracking, the distress was found to occur at a maximum asphalt layer thickness of 3-5 inches. A shift function was obtained for the bottom-up cracking to shift the thin sections from the constant strain state to match with the model, which was developed using the constant stress state.

- Alligator cracking showed no significant difference at different MAAT. In fact, the alligator cracking appeared to be the same for a wide range in temperature.

- The Design Guide computer code calculates the tensile strains for the damage computation at the bottom of every asphalt layer to assess the damage caused by alligator (bottom-up) cracking. For the longitudinal (surface down) cracking, tensile strains were calculated at the surface of the pavement (Z=0") and at 0.5" deep from the surface. It was concluded (without question) that tensile strains and hence fatigue damage, were greatest at pavement surface directly between the dual tire of any gear type.

- An analysis of the calibration results for the Shell Oil model showed that this model had more scatter. No definite trends, at all, were found for the longitudinal cracking. A comparison of the initial accuracy of both model approaches (Shell Oil and the Asphalt Institute) led to the decision to abandon the Shell Oil approach from further consideration and only concentrate upon enhancing the Asphalt Institute's MS-1 approach.

- The MS-1 model was found to have better trends and less scatter in the data than the Shell Oil model. However, because the MS-1 is essentially a constant stress model; it was deemed necessary to apply (develop) corrections for the thinner sections by applying a shift factor to match with the thicker asphalt thickness. This adjustment can simply be viewed as an empirical, adjustment to account for constant strain conditions.

- The final values of the fatigue calibration factors were the β_{f2} = 1.2 on the tensile strain coefficient and β_{f2} = 1.5 on the modulus (E) coefficient. These calibration factors were found to be applicable for both the top-down and the bottom-up cracking due to the fact that both of the two distresses showed the least sum of error square for this combination of the distress model coefficients in the final optimization process.

- Thin AC sections were shifted for the alligator cracking calibration process using an adjustment equation including a function of the AC layer thickness.

$$N_f = 0.00432 * \beta_{f1} * C\left(\frac{1}{\varepsilon_t}\right)^{3.9492}\left(\frac{1}{E}\right)^{1.281}$$

$$\beta_{f1} = \beta'_{f1} * k'_1$$

$$k'_1 = \frac{1}{0.000398 + \frac{0.003602}{1 + e^{(11.02-3.49*hac)}}}$$

where:

h_{ac} = Total thickness of the asphalt concrete layers.

In the calibration analysis, it was determined that the most appropriate value of the β'_{f1} value turned to be β'_{f1} = 1.0.

The statistical summary for the final N_f model is:

Sum of error square	=	1.92E-07
Standard error (S_e)	=	0.00017

- The final alligator field calibrated cracking model was fund to be:

$$F.C. = \left(\frac{6000}{1 + e^{(C_1 * C'_1 + C_2 * C'_2 * \log10(D*100))}}\right) * \left(\frac{1}{60}\right)$$

where:

$C_1 = 1.0$
$C_2 = 1.0$
$C'_2 = -2.40874 - 39.748 * (1 + hac)^{-2.856}$

$C'_1 = -2 * C'_2$.

Number of observations	=	461 observations.
Sum of error square	=	17663.91
Standard error (S_e)	=	6.2 %.
S_e/S_y	=	0.947.

- The standard deviation of the alligator cracking error was correlated to the predicted damage for the calculation of the reliability as given in the following equation:

$$Se_{FCBottom} = 0.5+12/(1+e^{1.308-2.949*\log D})$$

- An analysis of the LTPP database showed that longitudinal surface cracking, hypothesized to initiate due to surface tensile strains, appeared to be maximized at AC thickness of 5-7 inches. A shift function was developed for the top-down cracking in order for the predicted cracking to match the measured cracking from the LTPP database at different asphalt layer thickness.

- The effect of longitudinal cracking was found to be greater at higher mean annual air temperatures (MAAT) (about 50-60 ºF) than was expected. In addition, it was found that the foundation stiffness slightly influenced the degree of top-down cracking. The stiffer the foundation layer, the greater the amount of longitudinal cracking distress.

- In the initial study of top down cracking, two different depths were used to assess the damage. These depths were at the surface of the pavement and at a 0.5 inch deep in the surface layer. Further studies clearly showed that the tensile strain at the 0.5-inch deep strains were always less than the surface. As a consequence, only the surface tensile strains (between the tires) were eventually used in the calibration process.

- Three different methods of calculating the longitudinal cracking were initially investigated to assess which approach would provide the most accurate methodology. In all three approaches, the load-associated strains at the surface (in a direction parallel to traffic) were added to a thermal strain computed from: the maximum thermal strain, the average thermal strain and a null case where no thermal strains were added. The maximum damage (tensile strain) in both directions to traffic (parallel and normal) was evaluated. It was concluded that the best correlation and least scatter occurred for the case when thermal strain were not considered in the analysis.

- The top-down cracking final calibration model developed was:

$$N_f = 0.00432 * \beta'_{f1} * k_1' * C\left(\frac{1}{\varepsilon_t}\right)^{3.9492}\left(\frac{1}{E}\right)^{1.281}$$

$$k'_1 = \frac{1}{0.0001 + \frac{29.844}{1 + e^{(30.544-5.7357*hac)}}}$$

While the transfer function, relating damage to the amount of longitudinal cracking, was found to be:

$$F.C. = \left(\frac{1000}{1 + e^{(7-3.5*\log 10(D*100))}}\right) * 10.56$$

Number of observations	=	414 observations.
Sum of error square	=	6.37e8
Standard error (S_e)	=	1242.25 ft/mile.
S_e/S_y	=	0.977.

Similar to the bottom up cracking, it was found that the most appropriate value of the β'_{f1} value was β'_{f1} = 1.0.

- The standard deviation for the top-down cracking error was correlated to the predicted damage for the calculation of the reliability. The relationship found is shown in the following equation:

$$STD_{FCTop} = 200+2300/(1+e^{1.072-2.1654*\log D})$$

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Annex B

Bottom-Up Alligator Fatigue Cracking Shell Oil Model Calibration

Table B-1 Measured Alligator Cracking Fatigue Cracking and Predicted Bottom-up Damage Using Shell Oil Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.9,0.9	0.9,1.0	0.9,1.1	1.0,0.9	1.0,1.0
11001	3.2	Sep-91	132	8	0	0	8	10700	68740	445000	148.5	942.6
11001	3.2	Apr-92	139	13	0	0	13	11390	73410	477200	157.1	1001
11001	3.2	Jul-92	142	13	0	0	13	11700	75320	488900	161.7	1029
11001	3.2	Jan-93	148	45	0	0	45	12280	79170	514700	169.4	1079
11019	6.7	May-89	32	0	0	0	0	9490	54380	313100	120	683.6
11019	6.7	Apr-90	43	0	0	0	0	12840	73530	423300	161.3	918.2
11019	6.7	Jan-91	52	0	0	0	0	15680	89530	513900	197.1	1118
11019	6.7	Jun-91	57	800	0	0	800	17400	99320	570000	218.5	1239
11019	6.7	Mar-92	66	0	0	0	0	20360	116400	669000	254.6	1446
11019	6.7	Mar-93	78	1112	0	0	1112	24530	140200	804900	306.4	1739
11019	6.7	Jul-95	106	2554	0	0	2554	34800	198300	1136000	435.1	2462
11019	6.7	Jan-98	136	0	1461	233	1693	45940	262000	1502000	572.5	3243
14126	13.1	Jun-89	15	0	0	0	0	239.1	1405	8285	1.751	10.21
14126	13.1	Mar-91	36	0	0	0	0	625.9	3660	21500	4.621	26.8
14126	13.1	Mar-93	60	0	0	0	0	1100	6437	37840	8.113	47.11
14126	13.1	Apr-94	73	0	0	0	0	1388	8133	47840	10.24	59.47
14126	13.1	Dec-95	93	6	22	0	28	1904	11140	65430	14.08	81.75
14126	13.1	Dec-97	117	81	0	0	81	2485	14560	85660	18.34	106.6
21001	3	May-90	83	0	0	0	0	38.45	280.1	2049	0.421	3.043
21001	3	Aug-91	98	0	0	0	0	46.21	335.8	2451	0.5076	3.66
21001	3	Aug-93	122	0	0	0	0	57.98	421.7	3081	0.6368	4.595
21001	3	Jun-95	144	0	0	0	0	67.69	493.5	3614	0.7406	5.356
21001	3	Aug-97	170	0	0	0	0	80.79	588.8	4311	0.8841	6.392
21001	3	Aug-98	182	0	3	0	3	86.6	631.1	4620	0.9479	6.853
21002	3.3	May-90	68	0	0	0	0	5.11	37.74	280.2	0.05174	0.3783
21002	3.3	Aug-91	83	0	0	0	0	6.519	48.03	355.7	0.06628	0.4836
21002	3.3	Aug-93	107	0	0	0	0	8.424	62.17	461.1	0.08547	0.6244
21002	3.3	Jun-95	129	0	0	0	0	10.02	74.15	551.4	0.1013	0.7414
21002	3.3	Aug-97	155	0	0	0	0	12.27	90.73	674.4	0.1241	0.908
21002	3.3	May-98	164	0	0	0	0	12.74	94.4	703.1	0.1283	0.9411
40113	4.5	Feb-95	19	11	0	0	11	661.1	4102	25710	7.601	46.42
40113	4.5	Mar-95	20	11	0	0	11	701.9	4368	27450	8.034	49.23
40113	4.5	Aug-95	25	11	0	0	11	948	5797	35800	11.13	67.07
40113	4.5	Nov-95	28	11	0	0	11	1107	6756	41620	13.02	78.4
40113	4.5	Feb-96	31	11	0	0	11	1197	7388	46030	13.86	84.22
40113	4.5	Apr-96	33	11	0	0	11	1300	8032	50100	15.02	91.43
40113	4.5	Jul-96	36	11	0	0	11	1477	9036	55800	17.32	104.4
40113	4.5	Aug-96	37	11	0	0	11	1542	9394	57800	18.18	109.2
40113	4.5	Jan-98	54	11	0	0	11	2415	14890	92840	27.98	169.7
40113	4.5	Apr-98	57	11	10	0	20	2566	15900	99570	29.51	179.8
40113	4.5	Jun-98	59	11	10	0	20	2714	16760	104600	31.36	190.6
40113	4.5	Oct-98	63	11	10	0	20	3038	18620	115400	35.49	214.2
40114	6.8	Feb-95	19	11	0	0	11	2868	18030	114100	30.11	186.9
40114	6.8	Mar-95	20	11	0	0	11	2965	18700	118800	30.94	192.6
40114	6.8	Aug-95	25	11	0	0	11	4458	27840	174800	47.37	292.6

Table B-1 (Cont'd) Measured Alligator Cracking Fatigue Cracking and Predicted Bottom-up Damage Using Shell Oil Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.9,0.9	0.9,1.0	0.9,1.1	1.0,0.9	1.0,1.0
40114	6.8	Nov-95	28	11	0	0	11	5200	32520	204400	55.08	340.9
40114	6.8	Feb-96	31	11	0	0	11	5327	33450	211200	56	347.6
40114	6.8	Apr-96	33	11	0	0	11	5667	35690	226100	59.22	368.7
40114	6.8	Jul-96	36	11	0	0	11	6841	42820	269400	72.27	447.7
40114	6.8	Aug-96	37	11	0	0	11	7302	45580	286000	77.48	478.9
40114	6.8	Jan-98	54	11	0	0	11	10810	67810	427800	113.6	704.8
40114	6.8	Apr-98	57	11	46	0	57	11150	70160	444100	116.5	724.6
40114	6.8	Jun-98	59	11	52	0	62	11950	75100	474800	125	777.2
40114	6.8	Oct-98	63	11	114	0	125	13960	87450	550500	147.1	912.1
40115	15.1	Feb-95	19	11	0	0	11	13.86	81.9	486.1	0.09003	0.5272
40115	15.1	Mar-95	20	11	25	0	36	14.13	83.71	498.2	0.09137	0.536
40115	15.1	Jan-98	54	11	0	0	11	47.93	282.9	1676	0.3106	1.819
40116	16.2	Feb-95	19	11	0	0	11	11.42	69.84	428.9	0.06596	0.3998
40116	16.2	Mar-95	20	11	0	0	11	11.63	71.3	439	0.06687	0.406
40116	16.2	Jan-98	54	11	0	0	11	39.83	243.3	1492	0.2297	1.392
40117	11.8	Feb-95	19	11	0	0	11	218.1	1313	7938	1.807	10.79
40117	11.8	Mar-95	20	11	0	0	11	221.4	1336	8089	1.826	10.92
40117	11.8	Jan-98	54	11	0	0	11	804.9	4855	29380	6.62	39.65
40118	11.7	Feb-95	19	11	0	0	11	106.5	656.7	4066	0.7833	4.784
40118	11.7	Mar-95	20	11	0	0	11	109	674.1	4186	0.7978	4.883
40118	11.7	Jan-98	54	11	0	0	11	401.3	2470	15260	2.971	18.14
41007	6.5	Sep-91	162	38	0	0	38	4066	24170	144500	46.06	271
41007	6.5	Feb-93	163	44	16	0	60	4113	24450	146200	46.57	274
41007	6.5	Sep-94	198	70	132	0	202	5646	33570	200800	63.9	376.1
41024	10.8	Nov-89	149	0	0	0	0	59030	342700	1996000	581.9	3354
41024	10.8	Aug-90	158	0	0	0	0	64100	372400	2171000	630.9	3638
41024	10.8	Oct-92	184	0	0	0	0	82320	478800	2795000	807.5	4664
41024	10.8	Mar-95	213	0	0	0	0	103200	600100	3502000	1014	5851
41024	10.8	Jul-95	217	0	0	0	0	108100	628300	3666000	1061	6125
41024	10.8	Aug-95	218	12	0	0	12	109900	638900	3727000	1079	6230
41024	10.8	Nov-95	221	0	10	0	10	112300	653200	3814000	1101	6357
41024	10.8	Feb-96	224	0	0	0	0	112400	654200	3821000	1101	6362
41024	10.8	Apr-96	226	16	0	0	16	113300	659900	3857000	1109	6410
41024	10.8	Jun-96	228	118	0	0	118	117200	682000	3985000	1147	6632
41024	10.8	Aug-96	230	161	0	0	161	122900	714300	4165000	1208	6973
41024	10.8	Apr-98	250	0	398	529	927	136900	797400	4662000	1338	7738
41024	10.8	Jun-98	252	0	397	530	927	141000	821400	4801000	1380	7978
41024	10.8	Oct-98	256	0	414	529	943	149700	870700	5081000	1468	8477
81029	4.2	Oct-91	233	27	15	0	42	48.49	329.8	2263	0.572	3.828
81029	4.2	Jul-94	266	0	0	0	0	55.16	375.4	2578	0.6492	4.347
81029	4.2	Sep-95	280	464	0	0	464	58.45	397.8	2731	0.6877	4.605
81053	4.6	Oct-89	60	0	0	0	0	41.91	276.2	1838	0.5014	3.253
81053	4.6	Jul-90	69	0	0	0	0	49.72	328.6	2192	0.5921	3.848
81053	4.6	Apr-93	102	3	0	0	3	82.54	547.2	3663	0.9742	6.349
81053	4.6	Nov-93	109	0	0	0	0	93.2	615.3	4101	1.106	7.18
81053	4.6	Dec-93	110	23	0	0	23	93.4	616.9	4113	1.107	7.191

Table B-1 (Cont'd) Measured Alligator Cracking Fatigue Cracking and Predicted Bottom-up Damage Using Shell Oil Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.9,0.9	0.9,1.0	0.9,1.1	1.0,0.9	1.0,1.0
81053	4.6	Oct-94	120	0	0	0	0	108.8	717.6	4777	1.293	8.39
81053	4.6	Feb-95	124	40	0	0	40	111.2	736.5	4924	1.314	8.553
81053	4.6	May-95	127	40	0	0	40	115.6	766.3	5127	1.364	8.886
81053	4.6	May-96	139	0	0	0	0	132.5	878.3	5877	1.563	10.18
81053	4.6	Oct-96	144	310	0	0	310	144.1	950.7	6331	1.711	11.1
81053	4.6	Nov-96	145	253	0	0	253	144.9	956.3	6374	1.718	11.15
81053	4.6	Mar-97	149	457	0	0	457	147.9	979.1	6543	1.748	11.37
91803	7.2	Jul-89	49	0	0	0	0	924	5989	39090	10.17	65.09
91803	7.2	Sep-90	63	0	0	0	0	1320	8529	55480	14.61	93.23
91803	7.2	Aug-91	74	0	0	0	0	1597	10340	67360	17.64	112.7
91803	7.2	Sep-92	87	8	0	0	8	1996	12920	84290	21.98	140.6
91803	7.2	May-94	107	211	0	0	211	2545	16580	108800	27.76	178.3
91803	7.2	May-95	119	240	0	0	240	3005	19570	128400	32.8	210.7
91803	7.2	Oct-96	136	84	82	0	166	3906	25320	165400	42.96	274.8
91803	7.2	May-97	143	301	0	0	301	4075	26520	173900	44.52	285.7
91803	7.2	Sep-97	147	15	325	0	340	4464	28940	189000	49.08	314
91803	7.2	Jun-98	156	195	0	0	195	4795	31200	204600	52.4	336.3
120103	12	Dec-96	14	0	0	0	0	9.777	61.93	392.6	0.06557	0.4145
120104	18	Dec-96	14	0	0	0	0	0.5557	3.526	22.39	0.0027	0.01711
120105	7.9	Dec-96	14	0	0	0	0	118.5	762.6	4914	1.053	6.761
120106	15	Dec-96	14	0	0	0	0	1.708	10.8	68.31	0.00949	0.05987
123995	5	Apr-92	197	0	0	0	0	28720	189300	1250000	298.2	1957
123995	5	Mar-94	220	86	0	0	86	32410	213700	1413000	336.3	2208
123995	5	Jan-96	242	58	0	0	58	36130	238300	1575000	374.8	2461
123995	5	Jan-96	243	122	0	0	122	36260	239200	1581000	375.9	2469
123997	3.1	Aug-90	195	0	0	0		1266	8218	53670	17.06	109.8
123997	3.1	Oct-91	209	0	0	0		1418	9204	60100	19.13	123
123997	3.1	Mar-93	226	0	0	0		1615	10500	68780	21.7	139.9
123997	3.1	Mar-94	238	0	0	0		1763	11480	75220	23.67	152.8
124105	2.3	Apr-89	53	0	0	0	0	6895	45480	301900	105	687.4
124105	2.3	Oct-91	83	0	0	0	0	12060	79320	524800	184.6	1205
124105	2.3	Mar-93	100	0	0	0	0	15160	100200	667100	230.3	1511
124106	8.2	Apr-89	21	0	0	0	0	2313	14160	86860	21.37	130.4
124106	8.2	Feb-91	43	0	0	0	0	5086	31270	192700	46.5	285
124106	8.2	Jul-91	48	0	0	0	0	5867	36010	221400	53.81	329.1
124106	8.2	Mar-94	80	0	0	0	0	10290	63480	392400	93.4	574.3
124106	8.2	Jan-97	114	0	0	0	0	15620	96410	596400	141.6	871.2
124107	2.7	Dec-89	75	0	0	0	0	289.9	1913	12670	4.051	26.61
124107	2.7	Feb-91	89	0	0	0	0	367.5	2435	16190	5.108	33.69
124107	2.7	Jul-91	94	0	0	0	0	395.9	2622	17420	5.507	36.3
124107	2.7	Mar-93	114	732	355	9	1096	522.2	3466	23090	7.243	47.85
124107	2.7	Mar-94	126	656	243	0	899	605.5	4023	26820	8.389	55.48
124107	2.7	Jan-96	148	264	812	93	1168	770.3	5121	34170	10.66	70.55
124107	2.7	Mar-97	162	44	372	1224	1640	885.6	5898	39420	12.23	81.07
124108	9.9	Apr-89	35	0	0	0	0	68.61	424.5	2636	0.5607	3.444
124108	9.9	Jan-91	56	0	0	0	0	115.3	713.9	4435	0.9381	5.769

Table B-1 (Cont'd) Measured Alligator Cracking Fatigue Cracking and Predicted Bottom-up Damage Using Shell Oil Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.9,0.9	0.9,1.0	0.9,1.1	1.0,0.9	1.0,1.0
124108	9.9	Oct-91	65	0	0	0	0	143.2	885.4	5490	1.169	7.178
124108	9.9	Mar-94	94	0	0	0	0	203.9	1267	7899	1.645	10.15
124108	9.9	Aug-94	99	0	0	0	0	227.4	1409	8760	1.845	11.35
124108	9.9	Jan-96	116	0	0	0	0	265.2	1648	10270	2.137	13.18
124135	1.4	Dec-89	227	1112	86	0	1198	117100	786100	5314000	2155	14340
124135	1.4	Jan-91	240	2045	355	0	2400	123600	830500	5617000	2271	15120
131031	11.1	Apr-91	119	0	0	0		289.5	1776	10950	2.307	14.02
131031	11.1	Jul-92	134	0	0	0		366.7	2248	13840	2.922	17.75
131031	11.1	Jan-93	140	0	0	0		391.4	2401	14800	3.115	18.93
131031	11.1	Apr-94	155	0	0	0		473.7	2907	17920	3.765	22.89
131031	11.1	Oct-94	161	0	0	0		541.6	3312	20350	4.328	26.24
131031	11.1	Aug-95	171	0	0	0		602.2	3690	22720	4.795	29.12
131031	11.1	Jan-96	176	0	0	0		623.6	3826	23590	4.953	30.12
131031	11.1	Apr-96	179	0	0	0		633.4	3891	24030	5.018	30.55
134111	8.7	Mar-89	101	0	0	0	0	603.1	3781	23860	6.666	41.33
134111	8.7	Mar-91	125	0	0	0	0	923.6	5801	36660	10.17	63.21
134111	8.7	Feb-92	136	316	0	0	316	1098	6889	43490	12.11	75.19
134112	15.9	May-89	144	0	0	0	0	420.8	2469	14540	3.619	21.06
134112	15.9	Feb-91	165	0	0	0	0	526.6	3094	18250	4.514	26.31
134112	15.9	Apr-91	167	0	0	0	0	533.3	3136	18510	4.563	26.62
134112	15.9	Feb-94	201	0	0	0	0	740.7	4345	25600	6.363	37.03
134112	15.9	Oct-94	209	0	0	0	0	809	4744	27920	6.956	40.47
134112	15.9	Jan-96	224	0	0	0	0	892.6	5244	30930	7.643	44.56
134112	15.9	Feb-97	237	0	0	0	0	985.2	5784	34090	8.448	49.2
134112	15.9	Apr-98	251	0	0	0	0	1077	6331	37380	9.202	53.68
134113	15.2	May-89	144	0	0	0	0	1866	10830	63080	17.56	101.1
134113	15.2	Feb-91	165	0	0	0	0	2268	13180	76840	21.29	122.7
134113	15.2	Apr-91	167	0	0	0	0	2293	13330	77800	21.48	123.9
134113	15.2	Feb-94	201	0	0	0	0	3057	17740	103400	28.75	165.5
134113	15.2	Oct-94	209	0	0	0	0	3306	19180	111700	31.11	179.1
134113	15.2	Jan-96	224	0	0	0	0	3604	20940	122100	33.79	194.8
134113	15.2	Feb-97	237	47	0	0	47	3933	22840	133100	36.93	212.7
134113	15.2	Apr-98	251	44	0	0	44	4255	24740	144400	39.83	229.8
161001	3.7	Jul-89	192	0	0	0	0	620.2	4559	33880	6.207	44.64
161001	3.7	Aug-90	205	0	0	0	0	689.7	5065	37610	6.906	49.62
161001	3.7	Jun-93	239	36	0	0	36	866.6	6387	47590	8.604	62.05
161001	3.7	Aug-94	253	16	0	0	16	961.9	7074	52600	9.581	68.96
161001	3.7	May-95	262	0	0	0	0	1004	7403	55210	9.943	71.76
161001	3.7	Jul-97	288	3	611	0	615	1184	8724	64990	11.74	84.66
161001	3.7	Sep-98	302	0	434	99	533	1290	9497	70680	12.8	92.26
161009	10.4	Sep-89	180	0	0	0		65.81	424.7	2756	0.4587	2.927
161009	10.4	Jul-90	190	0	0	0		70.66	456.3	2964	0.492	3.141
161009	10.4	Jul-92	214	0	0	0		85.09	550	3577	0.5912	3.778
161009	10.4	Oct-93	229	0	0	0		97.49	629.5	4090	0.6787	4.333
161009	10.4	Jun-96	261	0	0	0		120.4	779	5069	0.8362	5.346
161009	10.4	Jul-97	274	0	0	0		133.8	864.6	5622	0.9298	5.941

Table B-1 (Cont'd) Measured Alligator Cracking Fatigue Cracking and Predicted Bottom-up Damage Using Shell Oil Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.9,0.9	0.9,1.0	0.9,1.1	1.0,0.9	1.0,1.0
161021	5.9	Sep-89	48	0	0	0	0	24.34	156.4	1014	0.2408	1.524
161021	5.9	Oct-90	61	0	0	0	0	30.73	197.9	1286	0.3029	1.92
161021	5.9	Aug-91	71	0	0	0	0	35.24	226.6	1470	0.3483	2.205
161021	5.9	Aug-93	95	0	0	0	0	47.73	307.6	2000	0.4701	2.98
161021	5.9	Sep-95	120	0	0	0	0	60.98	392.7	2552	0.6009	3.807
161021	5.9	Jun-96	129	0	0	0	0	63.73	411.4	2680	0.6259	3.973
161021	5.9	Jul-97	142	0	0	0	0	71.5	461.2	3003	0.7027	4.458
169034	9.2	Jul-89	10	0	0	0	0	10.62	69.68	460	0.08236	0.5331
169034	9.2	Aug-90	23	0	0	0	0	31.34	200.1	1286	0.2559	1.613
169034	9.2	Jun-93	57	0	0	0	0	67.77	436.2	2827	0.5441	3.456
169034	9.2	Aug-94	71	0	0	0	0	90.88	581.1	3740	0.7392	4.666
169034	9.2	May-95	80	0	0	0	0	95.65	613.9	3968	0.7725	4.891
169034	9.2	Jul-97	106	25	0	0	25	131.2	840.2	5418	1.064	6.722
169034	9.2	Sep-98	120	0	0	25	25	151.9	971.3	6253	1.234	7.79
201009	11.1	Aug-88	44	10	0	0	10	10.15	62.72	389	0.07557	0.4635
201009	11.1	May-89	53	0	0	0	0	11.11	68.92	429.3	0.08198	0.5045
201009	11.1	Dec-90	72	42	0	0	42	16.36	101.1	626.7	0.1216	0.7451
201009	11.1	Oct-91	82	1	13	0	14	18.94	117.1	726.8	0.1404	0.8612
201009	11.1	Apr-93	100	6	18	16	41	22.41	138.5	859.6	0.1662	1.019
201009	11.1	Apr-95	124	2	54	0	56	27.75	171.8	1067	0.2047	1.257
201009	11.1	Apr-96	136	0	0	0	0	30.44	188.5	1172	0.2243	1.377
201009	11.1	Jan-99	168	0	1643	0	1643	39.61	245	1522	0.2919	1.792
251003	6.6	Aug-89	180	0	0	0	0	2800	18520	123300	30.44	198.5
251003	6.6	Sep-90	193	0	0	0	0	3060	20250	134900	33.22	216.7
251003	6.6	Aug-91	204	28	0	0	28	3273	21670	144500	35.49	231.7
251003	6.6	Sep-92	217	56	93	0	149	3593	23760	158300	39.05	254.6
251003	6.6	Oct-95	254	45	75	0	121	4388	29070	193900	47.52	310.3
251003	6.6	Oct-96	266	1314	0	0	1314	4675	30970	206600	50.59	330.4
251003	6.6	Jun-98	286	1062	62	0	1125	5135	34040	227200	55.54	362.8
251004	9.6	Aug-89	178	0	0	0	0	1395	8941	57530	15.21	96.58
251004	9.6	Sep-90	191	0	0	0	0	1573	10080	64850	17.14	108.9
251004	9.6	Aug-91	202	0	0	0	0	1704	10920	70270	18.58	118
251004	9.6	Sep-92	215	0	0	0	0	1889	12110	77970	20.56	130.6
251004	9.6	Oct-95	252	0	0	0	0	2495	16000	103000	27.16	172.6
251004	9.6	Jun-97	272	56	0	0	56	2778	17840	115000	30.14	191.7
251004	9.6	Jun-98	284	0	0	0	0	3035	19480	125600	32.94	209.5
261001	2.2	Jul-88	203	0	0	0	0	51.73	381.4	2837	0.6647	4.831
261001	2.2	Sep-89	217	0	0	0	0	55.26	407	3024	0.7112	5.164
261001	2.2	Jul-90	227	0	0	0	0	57.56	424.4	3157	0.7395	5.374
261001	2.2	Jul-91	239	33	0	0	33	60.8	448.4	3335	0.781	5.677
261001	2.2	Sep-91	241	28	0	0	28	61.42	452.7	3366	0.7894	5.736
261001	2.2	Sep-92	253	40	0	0	40	64.33	474.5	3531	0.8257	6.004
261001	2.2	Jun-93	262	0	81	0	81	66.63	491.9	3663	0.8544	6.217
261001	2.2	Jun-93	263	76	0	0	76	66.96	494.1	3678	0.8592	6.249
261001	2.2	May-95	285	58	0	0	58	72.13	532.6	3967	0.9247	6.729
261001	2.2	Jul-96	299	83	0	0	83	76.02	561	4177	0.9753	7.094

Table B-1 (Cont'd) Measured Alligator Cracking Fatigue Cracking and Predicted Bottom-up Damage Using Shell Oil Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.9,0.9	0.9,1.0	0.9,1.1	1.0,0.9	1.0,1.0
261004	4.2	Sep-89	51	0	0	0	0	55.36	357.1	2322	0.7673	4.883
261004	4.2	Jul-90	61	0	0	0	0	64.65	418.6	2733	0.8916	5.693
271018	4.4	Apr-89	124	0	0	0	0	807.4	5391	36230	9.042	59.69
271018	4.4	Jun-89	126	0	0	0	0	842.6	5623	37760	9.446	62.34
271018	4.4	Oct-90	142	0	0	0	0	999.6	6663	44690	11.21	73.94
271018	4.4	Jun-93	174	0	0	0	0	1310	8741	58700	14.69	96.89
271018	4.4	Jul-93	176	0	0	0	0	1350	8999	60350	15.16	99.91
271018	4.4	Mar-94	183	0	0	0	0	1381	9222	61970	15.45	102
271018	4.4	Aug-94	188	0	0	0	0	1490	9933	66660	16.7	110.1
271087	15.7	Oct-91	154	0	0	0		0.886	5.685	36.58	0.00437	0.02789
271087	15.7	May-93	173	0	0	0		0.9545	6.13	39.47	0.0047	0.03001
271087	15.7	Oct-94	190	0	0	0		1.074	6.898	44.41	0.00529	0.03376
271087	15.7	Jun-96	210	0	0	0		1.161	7.461	48.08	0.00571	0.03646
291008	11.4	Feb-92	70	41	0	0	41	21.68	136	857.1	0.1493	0.9292
291008	11.4	Mar-93	83	140	22	0	161	26.16	164.2	1035	0.1803	1.122
291008	11.4	Mar-93	83	0	0	0	0	0	0	0	0	0
291008	11.4	Apr-96	120	0	0	0	0	41.51	260.8	1645	0.2865	1.784
291008	11.4	Feb-00	152	365	715	0	1080	58.06	364.4	2297	0.4015	2.499
307088	4.9	Sep-89	100	0	0	0	0	95.4	640.6	4343	1.107	7.297
307088	4.9	May-91	120	0	66	0	66	107	721.6	4918	1.225	8.11
308129	3.2	Oct-89	17	0	0	0	0	28.37	189.9	1283	0.38	2.508
308129	3.2	Jul-91	38	0	0	0	0	55.07	376.6	2601	0.7044	4.739
308129	3.2	Jul-92	50	0	0	0	0	70.17	481.5	3339	0.8875	5.992
308129	3.2	Aug-93	63	0	0	0	0	87.13	598.7	4157	1.094	7.396
308129	3.2	Dec-93	67	0	0	0	0	91.77	632.4	4404	1.145	7.764
308129	3.2	Mar-94	70	0	0	0	0	94.73	655.3	4581	1.175	7.989
308129	3.2	Oct-94	77	0	0	0	0	107.7	741	5153	1.345	9.108
308129	3.2	Feb-95	81	0	0	0	0	111.6	771.6	5391	1.385	9.412
308129	3.2	May-95	84	0	0	0	0	117.3	811.4	5673	1.454	9.893
308129	3.2	Jun-96	97	0	0	0	0	136.5	945.2	6614	1.686	11.48
308129	3.2	Oct-96	101	0	0	0	0	143.3	989.8	6910	1.774	12.06
308129	3.2	Jan-97	104	0	0	0	0	146.4	1014	7097	1.805	12.29
308129	3.2	Mar-97	106	0	0	0	0	148.9	1033	7246	1.83	12.49
308129	3.2	Aug-97	111	0	0	0	0	160.4	1109	7743	1.985	13.49
308129	3.2	Oct-97	113	0	0	0	0	163.7	1131	7901	2.025	13.76
321020	7	Jul-91	86	0	0	0	0	272.3	1787	11800	2.461	15.95
321020	7	Aug-93	111	18	0	0	18	385	2525	16660	3.48	22.55
321020	7	Sep-94	123	187	62	0	250	437.4	2869	18930	3.948	25.58
321020	7	Apr-95	131	34	0	0	34	460.4	3029	20060	4.133	26.85
321020	7	Jun-97	157	672	1043	0	1715	594.9	3912	25890	5.341	34.68
321020	7	Jun-98	169	3269	36	0	3305	663.3	4363	28880	5.952	38.66
341031	7.3	Apr-92	224	280	12	0	292	1423	8921	56190	18.24	113.1
341031	7.3	Feb-93	234	598	11	0	609	1572	9854	62030	20.18	125.1
341031	7.3	Oct-95	266	0	652	305	957	2131	13350	84050	27.3	169.3
341031	7.3	Nov-95	267	574	8	0	581	2133	13370	84190	27.32	169.5
341033	7.4	Apr-92	211	79	0	0	79	353.4	2255	14480	3.574	22.53

Table B-1 (Cont'd) Measured Alligator Cracking Fatigue Cracking and Predicted Bottom-up Damage Using Shell Oil Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.9,0.9	0.9,1.0	0.9,1.1	1.0,0.9	1.0,1.0
341033	7.4	Feb-93	221	6	0	0	6	374.2	2388	15330	3.782	23.84
341033	7.4	Nov-95	254	15	0	0	15	447.4	2852	18290	4.531	28.54
341033	7.4	Jul-97	274	0	0	0	0	486.6	3104	19920	4.923	31.02
341034	11.1	Oct-89	48	0	0	0	0	55.31	362.1	2380	0.3461	2.247
341034	11.1	Sep-90	59	0	0	0	0	70.16	459.1	3016	0.4391	2.85
341034	11.1	Apr-92	78	0	0	0	0	88.96	583.7	3846	0.5533	3.597
341034	11.1	Feb-93	88	0	0	0	0	104.3	683.8	4503	0.6487	4.216
341034	11.1	Nov-95	121	0	0	0	0	160.5	1052	6916	0.9998	6.492
341034	11.1	Jul-97	141	129	75	0	205	194.1	1272	8366	1.21	7.852
350101	7.2	May-97	19	0	0	0	0	4229	26630	168600	50.37	313.4
350102	4.8	May-97	19	0	0	0	0	2864	18790	124200	38.01	245.9
350103	12.5	May-97	19	0	0	0	0	8266	50770	312900	83.78	510.2
350104	19.2	May-97	19	0	0	0	0	451.1	2750	16820	3.39	20.5
350105	9.9	May-97	19	0	0	0	0	93270	567000	3462000	1088	6548
350106	15.6	May-97	19	0	0	0	0	1699	10340	63150	14.66	88.45
351005	8.9	Oct-89	73	0	0	0	0	243.3	1548	9891	2.394	15.1
351005	8.9	Mar-91	90	0	0	0	0	325.8	2070	13200	3.226	20.3
351005	8.9	Oct-92	109	0	0	0	0	448.8	2856	18250	4.423	27.9
351005	8.9	Feb-94	125	0	0	0	0	546.1	3474	22190	5.387	33.95
351005	8.9	Mar-95	138	0	0	0	0	641.7	4088	26150	6.311	39.82
351005	8.9	Apr-97	163	0	0	0	0	869.9	5541	35440	8.556	53.98
351022	6.3	Oct-89	37	0	0	0	0	160.7	1044	6824	1.737	11.14
351022	6.3	Mar-91	54	0	0	0	0	227	1489	9835	2.404	15.53
351022	6.3	Oct-92	73	0	0	0	0	374.4	2436	15960	3.994	25.63
351022	6.3	Feb-94	89	0	0	0	0	465.7	3046	20070	4.92	31.71
351022	6.3	Mar-95	102	0	0	0	0	571.2	3733	24590	6.028	38.81
351022	6.3	Apr-97	127	0	0	0	0	791	5177	34150	8.303	53.53
351112	6.3	Dec-89	67	0	0	0	0	1009	6287	39370	11.56	71.31
351112	6.3	Jan-91	80	0	0	0	0	1177	7348	46120	13.41	82.87
351112	6.3	Mar-91	82	0	0	0	0	1183	7392	46440	13.46	83.22
351112	6.3	Jan-93	104	0	0	0	0	1546	9660	60670	17.56	108.6
351112	6.3	Feb-94	117	0	0	0	0	1717	10750	67610	19.45	120.4
351112	6.3	Oct-94	125	0	0	0	0	1880	11760	73950	21.27	131.7
351112	6.3	Mar-95	130	9	0	0	9	1899	11900	74950	21.43	132.8
351112	6.3	Apr-95	131	0	0	0	0	1906	11950	75270	21.49	133.2
351112	6.3	Jun-95	133	0	0	0	0	1952	12240	77100	22.01	136.5
351112	6.3	Nov-96	150	0	0	0	0	2254	14110	88760	25.45	157.7
351112	6.3	Apr-97	155	0	0	0	0	2280	14290	90040	25.68	159.2
351112	6.3	Sep-97	160	0	0	0	0	2415	15130	95190	27.25	168.8
371024	4.8	Nov-89	109	167	0	0	167	17.78	116.4	768.1	0.2128	1.371
371024	4.8	Mar-91	125	889	89	0	978	20.43	134.2	889.1	0.2427	1.568
371024	4.8	Apr-92	138	1442	308	342	2093	23.25	152.9	1014	0.2755	1.782
371802	4.5	Mar-91	66	36	0	0	36	3276	20450	128600	60.42	371.9
371802	4.5	Oct-92	85	51	36	0	86	4433	27560	172700	82.26	504.8
371802	4.5	Apr-94	103	1521	0	0	1521	5321	33230	209200	98.1	604.2
371802	4.5	Jul-95	118	1739	70	0	1809	6239	38910	244600	115.3	709.3

Table B-1 (Cont'd) Measured Alligator Cracking Fatigue Cracking and Predicted Bottom-up Damage Using Shell Oil Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.9,0.9	0.9,1.0	0.9,1.1	1.0,0.9	1.0,1.0
371802	4.5	Apr-96	127	2608	206	0	2814	6695	41820	263400	123.4	760.1
371992	2.4	Mar-91	14	0	0	0	0	113.7	789.2	5514	1.641	11.27
371992	2.4	Oct-92	33	2	0	0	2	312.5	2127	14590	4.649	31.31
371992	2.4	Apr-94	51	0	0	0	0	524.7	3640	25450	7.592	52.03
371992	2.4	Feb-96	73	0	0	0	0	846.9	5864	40950	12.29	84.06
404087	10.1	Jan-90	43	0	0	0	0	134	802.9	4833	1.567	9.306
404087	10.1	Oct-91	64	0	0	0	0	232.9	1391	8345	2.735	16.2
404087	10.1	Nov-92	77	0	0	0	0	278.3	1669	10060	3.241	19.27
404087	10.1	Feb-93	80	0	0	0	0	279.1	1675	10100	3.246	19.31
404087	10.1	Nov-94	101	0	0	0	0	407	2438	14670	4.744	28.18
404087	10.1	Feb-95	104	32	0	0	32	407.9	2445	14730	4.75	28.22
404087	10.1	Aug-95	110	0	0	0	0	450.7	2704	16300	5.24	31.16
404087	10.1	Jun-97	132	67	207	0	273	559.6	3370	20390	6.456	38.52
404163	11.5	Jan-90	34	0	0	0	0	865.9	5221	31570	8.476	50.73
404163	11.5	Mar-91	48	0	0	0	0	1113	6739	40940	10.77	64.7
404163	11.5	Oct-91	55	0	0	0	0	1469	8845	53420	14.37	85.91
404163	11.5	Nov-92	68	0	0	0	0	1748	10550	63860	17	101.8
404163	11.5	Mar-93	72	0	0	0	0	1756	10600	64260	17.04	102.1
404163	11.5	Nov-94	92	0	0	0	0	2372	14300	86550	23.04	138
404163	11.5	Apr-96	109	27	0	0	27	2674	16160	97960	25.86	155.1
404163	11.5	Aug-97	125	0	0	0	0	3150	19040	115500	30.41	182.5
404163	11.5	Jan-99	141	13	0	0	13	3458	20940	127200	33.21	199.6
404165	8.1	Jan-90	68	0	0	0	0	1367	8491	53000	12.82	78.97
404165	8.1	Mar-91	82	0	0	0	0	1604	9998	62610	14.95	92.36
404165	8.1	Oct-91	89	0	0	0	0	1904	11820	73700	17.88	110.1
404165	8.1	Nov-92	102	0	0	0	0	2176	13530	84550	20.36	125.5
404165	8.1	Mar-93	106	0	0	0	0	2188	13620	85240	20.43	126
404165	8.1	Oct-94	125	1	2	0	3	2693	16780	105100	25.08	154.9
404165	8.1	Nov-94	126	0	0	0	0	2702	16850	105500	25.14	155.3
404165	8.1	Apr-95	131	3	0	0	3	2722	17000	106600	25.27	156.3
404165	8.1	Jun-95	133	3	0	0	3	2794	17460	109600	25.92	160.4
404165	8.1	Apr-96	143	0	0	0	0	2980	18630	117000	27.59	170.8
404165	8.1	Nov-96	150	0	0	0	0	3306	20600	129000	30.77	190.1
404165	8.1	May-97	156	32	0	0	32	3359	20970	131600	31.18	192.8
404165	8.1	Sep-97	160	40	0	0	40	3578	22300	139700	33.31	205.7
421599	12.3	Aug-89	25	0	0	0	0	53.71	326.9	1997	0.4042	2.441
421599	12.3	Sep-90	38	0	0	0	0	80.63	492.9	3025	0.5998	3.638
421599	12.3	Mar-93	68	0	0	0	0	144.2	882.9	5430	1.072	6.502
421599	12.3	Sep-94	86	0	0	0	0	203.5	1244	7637	1.515	9.183
421599	12.3	Jun-95	95	0	0	0	0	220.9	1352	8317	1.642	9.968
421599	12.3	Jul-96	108	0	0	0	0	264.3	1616	9928	1.969	11.94
421599	12.3	Mar-98	128	9	0	0	9	321.6	1970	12120	2.389	14.5
451011	3.2	Mar-92	69	0	0	0	0	776	5096	33730	9.786	63.5
451011	3.2	Oct-92	76	0	0	0	0	874.2	5707	37550	11.13	71.8
451011	3.2	Jun-93	84	1101	0	0	1101	965.3	6325	41770	12.22	79.11
451011	3.2	Jan-96	115	11	46	0	57	1331	8740	57840	16.79	108.9

Table B-1 (Cont'd) Measured Alligator Cracking Fatigue Cracking and Predicted Bottom-up Damage Using Shell Oil Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.9,0.9	0.9,1.0	0.9,1.1	1.0,0.9	1.0,1.0
451011	3.2	Jun-97	132	1729	41	150	1919	1536	10100	66910	19.34	125.6
451011	3.2	Feb-99	150	1203	612	254	2070	1767	11610	76830	22.28	144.6
473104	1.3	Aug-89	39	0	74	0	74	75.11	528.5	3753	1.639	11.36
473104	1.3	Nov-89	42	0	0	0	0	76.59	539.6	3837	1.661	11.53
473104	1.3	May-91	60	52	0	0	52	86.05	611.8	4390	1.805	12.63
473104	1.3	Aug-91	63	451	0	0	451	86.33	613.7	4403	1.809	12.66
473104	1.3	Oct-92	77	140	19	0	159	93.52	667.6	4808	1.92	13.49
473104	1.3	Aug-93	87	370	0	0	370	99.85	716.2	5183	2.016	14.22
473104	1.3	Nov-95	114	124	300	292	716	120.2	870.4	6353	2.338	16.65
473104	1.3	Oct-96	125	159	1217	407	1784	128.5	933.1	6830	2.467	17.63
480001	2.4	Apr-89	1	0	0	0	0	49.48	299.1	1814	0.9553	5.752
480001	2.4	Oct-90	19	0	0	0	0	1050	6274	37750	20.59	121.8
480001	2.4	May-91	26	0	0	0	0	1541	9407	57850	29.34	177.2
480001	2.4	Feb-93	47	0	0	0	0	3242	19880	123000	61.35	371.5
480001	2.4	Apr-93	49	0	0	0	0	3441	21120	130800	65	394.2
480001	2.4	Feb-95	71	0	0	0	0	5791	35550	220200	109.3	663.2
480001	2.4	Mar-95	72	0	0	0	0	5909	36310	225000	111.4	676.5
480001	2.4	May-97	98	0	18	0	18	9414	57990	360200	176.8	1076
480001	2.4	Mar-98	108	0	27	0	27	10930	67330	418500	205.1	1248
481060	7.5	Jun-90	52	0	0	0		45750	283200	1759000	479.6	2948
481060	7.5	Feb-91	60	0	0	0	0	55990	346600	2153000	586.3	3604
481060	7.5	Apr-91	62	0	0	0	0	58030	360000	2241000	605.1	3727
481060	7.5	Mar-92	73	0	0	0	0	74610	462400	2876000	779.1	4795
481060	7.5	Feb-93	84	8	0	0	8	92560	573900	3572000	965.4	5944
481060	7.5	Mar-93	85	0	0	0	0	93290	579000	3606000	971.5	5986
481060	7.5	Oct-94	104	0	0	0	0	136800	847400	5266000	1429	8793
481060	7.5	Feb-95	108	0	0	0	0	139200	863800	5381000	1448	8925
481060	7.5	Mar-95	109	0	0	0	0	140100	869900	5422000	1455	8976
481060	7.5	Mar-95	112	0	0	0	0	147300	915500	5709000	1529	9436
481060	7.5	Jun-95	134	0	0	0	0	195900	1218000	7606000	2028	12520
481060	7.5	Apr-97	137	0	0	0	0	208000	1292000	8056000	2158	13320
481060	7.5	Jul-97	139	12	0	0	12	217300	1348000	8393000	2261	13940
481060	7.5	Sep-97	154	0	0	0	0	255200	1586000	9893000	2645	16330
481077	5.1	Apr-89	88	0	0	0	0	747.8	4838	31600	7.392	47.08
481077	5.1	Nov-91	119	0	0	0	0	1072	6911	44980	10.64	67.54
481077	5.1	Oct-92	130	0	0	0	0	1190	7672	49930	11.8	74.95
481077	5.1	May-93	137	0	0	0	0	1241	8036	52530	12.23	77.95
481077	5.1	Oct-94	154	10	0	0	10	1447	9334	60790	14.34	91.07
481077	5.1	Mar-95	159	0	0	0	0	1477	9557	62440	14.57	92.75
481077	5.1	Apr-95	160	0	0	0	0	1489	9635	62970	14.68	93.46
481077	5.1	Jun-95	162	0	0	0	0	1519	9821	64140	14.98	95.36
481077	5.1	Aug-95	164	0	0	0	0	1553	10020	65320	15.37	97.65
481077	5.1	Jun-96	174	0	0	0	0	1652	10690	69880	16.28	103.7
481077	5.1	May-97	185	13	0	0	13	1773	11480	75120	17.43	111.1
481077	5.1	Jul-97	187	56	0	0	56	1807	11690	76380	17.81	113.4
481077	5.1	Sep-97	189	50	0	0	50	1842	11900	77630	18.19	115.7

Table B-1 (Cont'd) Measured Alligator Cracking Fatigue Cracking and Predicted Bottom-up Damage Using Shell Oil Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.9,0.9	0.9,1.0	0.9,1.1	1.0,0.9	1.0,1.0
481077	5.1	Mar-98	195	41	0	0	41	1889	12240	80070	18.57	118.4
481109	6.5	Jan-90	68	0	0	0	0	2443	12250	61640	49.64	247.5
481109	6.5	Sep-90	76	0	0	0	0	2832	14180	71180	57.7	287.3
481109	6.5	May-91	84	0	0	0	0	3130	15740	79350	63.31	316.6
481109	6.5	Feb-93	105	73	0	0	73	4100	20650	104400	82.6	413.9
481109	6.5	Jul-93	110	0	0	0	0	4389	22080	111400	88.59	443.4
481109	6.5	Feb-95	129	186	0	0	186	5313	26830	135800	106.6	535.2
481109	6.5	May-95	132	74	0	0	74	5488	27710	140300	110.1	552.8
481109	6.5	Aug-96	147	150	0	0	150	6369	32130	162600	127.9	641.8
481169	1.1	Feb-90	211	0	0	0	0	4734	28890	177400	81.68	497.9
481169	1.1	Mar-90	212	0	0	0	0	4761	29050	178300	82.16	500.6
481169	1.1	Sep-90	218	0	0	0	0	4820	29370	180100	83.19	506.3
481169	1.1	Jan-91	222	0	0	0	0	5026	30680	188400	86.72	528.5
481169	1.1	Mar-91	224	0	0	0	0	5100	31130	191100	88.01	536.4
481169	1.1	Jun-91	227	0	0	0	0	5132	31310	192100	88.57	539.4
481169	1.1	Jan-92	234	0	0	0	0	5373	32800	201500	92.71	565.1
481169	1.1	Feb-93	247	0	0	0	0	5772	35250	216500	99.58	607.2
481169	1.1	Aug-93	253	0	0	0	0	5846	35660	218900	100.9	614.5
481169	1.1	Mar-95	272	0	0	0	0	6507	39740	244100	112.3	684.6
481169	1.1	Jul-95	276	0	0	0	0	6549	39970	245400	113	688.6
481169	1.1	Jul-97	300	0	0	0	0	7288	44490	273300	125.7	766.5
481174	4.7	Oct-90	186	0	0	0	0	462.2	2864	17850	5.754	35.33
481174	4.7	Feb-91	190	0	0	0	0	467.6	2903	18120	5.808	35.7
481174	4.7	Apr-91	192	0	16	0	16	472.1	2932	18310	5.858	36.03
481174	4.7	Mar-92	203	0	0	0	0	500.8	3110	19430	6.213	38.22
481174	4.7	Feb-93	214	22	0	0	22	529.1	3286	20530	6.565	40.38
481174	4.7	Mar-93	215	58	0	0	58	531	3299	20620	6.586	40.52
481174	4.7	Feb-95	238	28	0	0	28	589.8	3665	22900	7.315	45.01
481174	4.7	Mar-95	239	109	0	0	109	591.8	3678	22990	7.336	45.15
481174	4.7	Jan-96	249	154	0	0	154	618	3839	23990	7.664	47.15
481174	4.7	Apr-97	264	492	6	0	498	655.4	4076	25490	8.116	49.98
481174	4.7	Mar-98	275	422	61	0	483	683.1	4248	26570	8.458	52.09
481178	8.5	Feb-91	32	0	0	0	0	38.41	222.5	1295	0.4225	2.427
481178	8.5	May-91	33	0	0	0	0	39.25	227.8	1328	0.4303	2.476
481178	8.5	Feb-93	56	0	0	0	0	73.08	424.4	2476	0.8014	4.616
481178	8.5	Jul-93	61	0	0	0	0	82.66	480.3	2803	0.9058	5.222
481178	8.5	Feb-95	80	9	0	0	9	114.1	664.1	3884	1.247	7.199
481178	8.5	Mar-95	81	9	0	0	9	114.8	669	3916	1.253	7.241
481183	5.7	Sep-90	188	0	0	0		1130	6731	40340	20.42	120.1
481183	5.7	Mar-91	194	0	0	0		1157	6909	41540	20.8	122.6
481183	5.7	Oct-91	201	0	0	0		1302	7765	46620	23.45	138.1
481183	5.7	Nov-91	202	0	0	0		1303	7778	46710	23.46	138.2
481183	5.7	Jan-93	216	0	0	0		1519	9048	54240	27.46	161.4
481183	5.7	Jul-93	222	0	0	0		1627	9700	58200	29.36	172.7
481183	5.7	Apr-94	231	0	0	0		1746	10430	62700	31.4	185

Table B-1 (Cont'd) Measured Alligator Cracking Fatigue Cracking and Predicted Bottom-up Damage Using Shell Oil Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.9,0.9	0.9,1.0	0.9,1.1	1.0,0.9	1.0,1.0
483749	1.8	Oct-90	116	0	0	0	0	4184	28200	191400	74.15	495.1
483749	1.8	Apr-91	122	0	0	0	0	4431	29970	204100	78.13	523.4
483749	1.8	Aug-91	126	0	0	0	0	4553	30740	209100	80.36	537.6
483749	1.8	Mar-92	133	0	0	0	0	4829	32700	223000	84.83	569
483749	1.8	Feb-93	144	55	132	41	228	5220	35380	241500	91.47	614.2
483749	1.8	Mar-93	145	47	75	0	123	5262	35680	243700	92.14	618.9
483749	1.8	Feb-95	168	210	172	177	559	6109	41490	283800	106.5	716.6
483749	1.8	Mar-95	169	41	1045	0	1086	6151	41790	285900	107.2	721.4
483749	1.8	Mar-97	193	115	343	1504	1962	7031	47840	327700	122.1	822.8
489005	1.2	Oct-90	50	126	0	0	126	13750	86980	553900	316.3	1992
489005	1.2	Mar-91	55	19	0	0	19	16630	106100	681300	380	2414
489005	1.2	Aug-91	60	75	0	0	75	17440	110700	708200	399.3	2525
489005	1.2	Feb-93	78	24	0	0	24	25110	160600	1034000	572.5	3643
489005	1.2	Apr-93	80	58	0	0	58	25920	165700	1066000	591.4	3762
489005	1.2	Feb-95	102	0	0	0	0	34150	218600	1410000	777.1	4951
489005	1.2	Feb-96	114	165	0	0	165	38860	249100	1608000	883.1	5633
489005	1.2	Jul-96	119	202	0	0	202	40160	257000	1656000	913.5	5817
489005	1.2	Jul-97	131	140	0	0	140	44770	286400	1845000	1018	6482
489005	1.2	Jul-98	143	110	0	0	110	49880	319500	2062000	1134	7228
501002	8.5	Aug-89	58	0	0	0	0	50.3	317.4	2013	0.4752	2.972
501002	8.5	Aug-90	70	0	0	0	0	60.49	382.1	2425	0.5705	3.57
501002	8.5	May-94	115	795	0	0	795	99.87	632.6	4028	0.9366	5.876
501002	8.5	Aug-94	118	306	0	0	306	107.6	679.3	4311	1.014	6.347
501002	8.5	Apr-95	126	692	0	0	692	110.6	699.8	4451	1.039	6.511
501002	8.5	Oct-96	144	41	301	0	342	133.8	845.9	5376	1.258	7.878
501002	8.5	May-97	151	121	31	0	152	136.6	865.1	5506	1.282	8.038
501002	8.5	Oct-97	156	667	121	0	788	147.1	929.3	5901	1.385	8.67
501002	8.5	Jun-98	164	85	632	0	717	151.9	961.1	6111	1.428	8.946
501004	8	Apr-93	102	0	0	0		330.8	2098	13380	3.483	21.81
501004	8	Oct-95	132	0	0	0		613.9	3874	24570	6.608	41.19
501004	8	Nov-97	157	0	0	0		717.7	4544	28920	7.537	47.12
511002	5.7	Apr-89	115	127	229	30	386	2045	13180	85450	27.48	174.7
511023	10.1	Oct-89	107	0	0	0	0	619.4	3818	23620	5.868	35.88
511023	10.1	Mar-91	124	0	0	0	0	693.3	4284	26580	6.531	40.03
511023	10.1	May-92	138	0	0	0	0	784.3	4849	30100	7.381	45.25
511023	10.1	Oct-92	143	13	0	0	13	844.4	5217	32360	7.953	48.74
511023	10.1	Dec-93	157	11	0	0	11	946.1	5842	36210	8.921	54.64
511023	10.1	Sep-95	178	61	0	0	61	1112	6867	42570	10.48	64.19
511023	10.1	Feb-96	183	182	0	0	182	1121	6932	43020	10.55	64.66
511023	10.1	Mar-97	196	276	0	0	276	1218	7532	46740	11.46	70.26
512021	7.5	Oct-89	54	0	0	0	0	353.4	2249	14390	3.501	22.07
512021	7.5	Mar-91	71	31	0	0	31	459.4	2927	18750	4.543	28.65
512021	7.5	Oct-92	90	0	0	0	0	620.5	3956	25350	6.126	38.67
531008	3.4	Jul-91	153	11	17	5	33	77.69	543.3	3841	0.8905	6.114
531008	3.4	Jun-93	176	25	24	6	55	90.58	634.5	4491	1.035	7.12
531008	3.4	Jun-94	188	135	439	414	988	97.71	684.6	4848	1.116	7.678

Table B-1 (Cont'd) Measured Alligator Cracking Fatigue Cracking and Predicted Bottom-up Damage Using Shell Oil Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.9,0.9	0.9,1.0	0.9,1.1	1.0,0.9	1.0,1.0
561007	2.8	Jul-90	121	0	0	0	0	42.14	292.5	2051	0.5401	3.692
561007	2.8	May-91	131	0	0	0	0	45.54	316.7	2224	0.5824	3.987
561007	2.8	Aug-91	134	0	0	0	0	46.9	325.6	2282	0.6013	4.109
561007	2.8	Aug-93	158	0	0	0	0	55.1	382.7	2686	0.7056	4.825
561007	2.8	Oct-93	160	0	0	0	0	55.85	388	2722	0.715	4.89
561007	2.8	Dec-93	162	5	0	0	5	56.34	391.7	2751	0.72	4.928
561007	2.8	Mar-94	165	8	0	0	8	57.06	397.1	2792	0.7283	4.989
561007	2.8	Apr-94	166	0	0	0	0	57.61	401	2820	0.7354	5.039
561007	2.8	Aug-94	170	6	0	0	6	59.39	412.8	2898	0.7595	5.197
561007	2.8	Feb-95	176	0	0	0	0	60.31	419.5	2947	0.7702	5.274
561007	2.8	May-95	179	0	0	0	0	61.6	428.8	3015	0.7862	5.387
561007	2.8	Sep-95	183	0	0	0	0	63.32	439.7	3084	0.8109	5.543
561007	2.8	Jun-96	192	12	0	0	12	66.27	460.9	3238	0.8466	5.796
561007	2.8	Oct-96	196	0	0	0	0	67.87	471.7	3311	0.8676	5.936
561007	2.8	Nov-96	197	0	0	0	0	68.09	473.4	3325	0.8698	5.953
561007	2.8	Mar-97	201	0	0	0	0	68.29	475	3337	0.8719	5.969
561007	2.8	Aug-97	206	0	0	0	0	70.95	493.1	3462	0.9075	6.209
561007	2.8	Sep-97	207	0	0	0	0	71.37	495.9	3480	0.9131	6.246

Table B-2 Measured Alligator Cracking Fatigue Cracking and Predicted Bottom-up Damage Using Shell Oil Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{12} and β_{13})			
				Low	Medium	High	Total	1.0,1.1	1.1,0.9	1.1,1.0	1.1,1.1
11001	3.2	Sep-91	132	8	0	0	8	6031	2.127	13.36	84.54
11001	3.2	Apr-92	139	13	0	0	13	6429	2.239	14.11	89.62
11001	3.2	Jul-92	142	13	0	0	13	6602	2.31	14.54	92.22
11001	3.2	Jan-93	148	45	0	0	45	6933	2.415	15.22	96.64
11019	6.7	May-89	32	0	0	0	0	3911	1.552	8.79	49.99
11019	6.7	Apr-90	43	0	0	0	0	5250	2.073	11.73	66.64
11019	6.7	Jan-91	52	0	0	0	0	6371	2.532	14.28	80.84
11019	6.7	Jun-91	57	800	0	0	800	7060	2.804	15.8	89.48
11019	6.7	Mar-92	66	0	0	0	0	8249	3.253	18.36	104.1
11019	6.7	Mar-93	78	1112	0	0	1112	9914	3.912	22.05	124.9
11019	6.7	Jul-95	106	2554	0	0	2554	14000	5.557	31.25	176.5
11019	6.7	Jan-98	136	0	1461	233	1693	18460	7.286	41.01	231.9
14126	13.1	Jun-89	15	0	0	0	0	59.7	0.01351	0.07827	0.4546
14126	13.1	Mar-91	36	0	0	0	0	156	0.03594	0.2071	1.197
14126	13.1	Mar-93	60	0	0	0	0	274.5	0.06304	0.3637	2.104
14126	13.1	Apr-94	73	0	0	0	0	346.7	0.0795	0.4588	2.655
14126	13.1	Dec-95	93	6	22	0	28	476.1	0.1096	0.6322	3.657
14126	13.1	Dec-97	117	81	0	0	81	621.5	0.1424	0.8224	4.762
21001	3	May-90	83	0	0	0	0	22.1	0.00478	0.03428	0.247
21001	3	Aug-91	98	0	0	0	0	26.51	0.00578	0.04134	0.2971
21001	3	Aug-93	122	0	0	0	0	33.31	0.00725	0.0519	0.3733
21001	3	Jun-95	144	0	0	0	0	38.92	0.0084	0.06028	0.4345
21001	3	Aug-97	170	0	0	0	0	46.43	0.01003	0.07194	0.5184
21001	3	Aug-98	182	0	3	0	3	49.77	0.01076	0.07714	0.5558
21002	3.3	May-90	68	0	0	0	0	2.78	0.00055	0.00395	0.02876
21002	3.3	Aug-91	83	0	0	0	0	3.546	0.0007	0.00507	0.03683
21002	3.3	Aug-93	107	0	0	0	0	4.585	0.0009	0.00654	0.04751
21002	3.3	Jun-95	129	0	0	0	0	5.457	0.00107	0.00773	0.05631
21002	3.3	Aug-97	155	0	0	0	0	6.68	0.00131	0.00947	0.06899
21002	3.3	May-98	164	0	0	0	0	6.936	0.00135	0.00978	0.07137
40113	4.5	Feb-95	19	11	0	0	11	286.3	0.09065	0.5456	3.313
40113	4.5	Mar-95	20	11	0	0	11	304.5	0.09536	0.5759	3.509
40113	4.5	Aug-95	25	11	0	0	11	407.8	0.1352	0.8041	4.821
40113	4.5	Nov-95	28	11	0	0	11	476	0.1583	0.9413	5.64
40113	4.5	Feb-96	31	11	0	0	11	516.4	0.1663	0.9963	6.019
40113	4.5	Apr-96	33	11	0	0	11	561.5	0.1798	1.079	6.533
40113	4.5	Jul-96	36	11	0	0	11	635.1	0.2101	1.25	7.499
40113	4.5	Aug-96	37	11	0	0	11	661.5	0.2216	1.314	7.853
40113	4.5	Jan-98	54	11	0	0	11	1040	0.3363	2.011	12.13
40113	4.5	Apr-98	57	11	10	0	20	1107	0.3523	2.115	12.82
40113	4.5	Jun-98	59	11	10	0	20	1170	0.3759	2.251	13.6
40113	4.5	Oct-98	63	11	10	0	20	1305	0.4296	2.557	15.35
40114	6.8	Feb-95	19	11	0	0	11	1167	0.3284	2.016	12.44
40114	6.8	Mar-95	20	11	0	0	11	1206	0.3356	2.066	12.78
40114	6.8	Aug-95	25	11	0	0	11	1816	0.5203	3.185	19.57

Table B-2 (Cont'd) Measured Alligator Cracking Fatigue Cracking and Predicted Bottom-up Damage Using Shell Oil Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})			
				Low	Medium	High	Total	1.0,1.1	1.1,0.9	1.1,1.0	1.1,1.1
40114	6.8	Nov-95	28	11	0	0	11	2119	0.6026	3.698	22.78
40114	6.8	Feb-96	31	11	0	0	11	2168	0.6094	3.747	23.14
40114	6.8	Apr-96	33	11	0	0	11	2307	0.6408	3.952	24.47
40114	6.8	Jul-96	36	11	0	0	11	2786	0.7886	4.843	29.86
40114	6.8	Aug-96	37	11	0	0	11	2972	0.8483	5.2	31.99
40114	6.8	Jan-98	54	11	0	0	11	4393	1.235	7.592	46.85
40114	6.8	Apr-98	57	11	46	0	57	4529	1.261	7.766	48.04
40114	6.8	Jun-98	59	11	52	0	62	4854	1.354	8.339	51.55
40114	6.8	Oct-98	63	11	114	0	125	5678	1.601	9.839	60.7
40115	15.1	Feb-95	19	11	0	0	11	3.097	0.0006	0.00352	0.02049
40115	15.1	Mar-95	20	11	25	0	36	3.156	0.00061	0.00356	0.02078
40115	15.1	Jan-98	54	11	0	0	11	10.68	0.00208	0.01208	0.07048
40116	16.2	Feb-95	19	11	0	0	11	2.431	0.00039	0.00237	0.0143
40116	16.2	Mar-95	20	11	0	0	11	2.474	0.0004	0.0024	0.01449
40116	16.2	Jan-98	54	11	0	0	11	8.463	0.00137	0.00822	0.04967
40117	11.8	Feb-95	19	11	0	0	11	64.56	0.0155	0.0919	0.5461
40117	11.8	Mar-95	20	11	0	0	11	65.45	0.01561	0.09268	0.5514
40117	11.8	Jan-98	54	11	0	0	11	238	0.05619	0.3346	1.996
40118	11.7	Feb-95	19	11	0	0	11	29.33	0.00595	0.03609	0.2194
40118	11.7	Mar-95	20	11	0	0	11	30.01	0.00604	0.03666	0.2233
40118	11.7	Jan-98	54	11	0	0	11	111.1	0.02266	0.1375	0.8367
41007	6.5	Sep-91	162	38	0	0	38	1602	0.5372	3.133	18.36
41007	6.5	Feb-93	163	44	16	0	60	1621	0.5429	3.168	18.56
41007	6.5	Sep-94	198	70	132	0	202	2225	0.7445	4.346	25.47
41024	10.8	Nov-89	149	0	0	0	0	19380	5.902	33.82	194.2
41024	10.8	Aug-90	158	0	0	0	0	21040	6.387	36.63	210.5
41024	10.8	Oct-92	184	0	0	0	0	27010	8.146	46.79	269.3
41024	10.8	Mar-95	213	0	0	0	0	33860	10.25	58.79	338.1
41024	10.8	Jul-95	217	0	0	0	0	35450	10.72	61.53	353.9
41024	10.8	Aug-95	218	12	0	0	12	36050	10.9	62.58	359.9
41024	10.8	Nov-95	221	0	10	0	10	36820	11.1	63.74	366.9
41024	10.8	Feb-96	224	0	0	0	0	36860	11.1	63.77	367.1
41024	10.8	Apr-96	226	16	0	0	16	37160	11.17	64.18	369.7
41024	10.8	Jun-96	228	118	0	0	118	38430	11.56	66.44	382.7
41024	10.8	Aug-96	230	161	0	0	161	40340	12.22	70.1	403.1
41024	10.8	Apr-98	250	0	398	529	927	44870	13.46	77.38	446
41024	10.8	Jun-98	252	0	397	530	927	46250	13.88	79.81	459.9
41024	10.8	Oct-98	256	0	414	529	943	49090	14.79	84.96	489.1
81029	4.2	Oct-91	233	27	15	0	42	25.81	0.00711	0.04691	0.3117
81029	4.2	Jul-94	266	0	0	0	0	29.32	0.00805	0.05316	0.3533
81029	4.2	Sep-95	280	464	0	0	464	31.06	0.00852	0.05627	0.374
81053	4.6	Oct-89	60	0	0	0	0	21.28	0.00639	0.0409	0.2636
81053	4.6	Jul-90	69	0	0	0	0	25.23	0.00752	0.0482	0.3111
81053	4.6	Apr-93	102	3	0	0	3	41.74	0.01228	0.07887	0.5104
81053	4.6	Nov-93	109	0	0	0	0	47.02	0.01399	0.08957	0.5777

Table B-2 (Cont'd) Measured Alligator Cracking Fatigue Cracking and Predicted Bottom-up Damage Using Shell Oil Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})			
				Low	Medium	High	Total	1.0,1.1	1.1,0.9	1.1,1.0	1.1,1.1
81053	4.6	Dec-93	110	23	0	0	23	47.11	0.014	0.08966	0.5784
81053	4.6	Oct-94	120	0	0	0	0	54.9	0.01638	0.1048	0.6757
81053	4.6	Feb-95	124	40	0	0	40	56.16	0.01657	0.1063	0.6871
81053	4.6	May-95	127	40	0	0	40	58.41	0.01717	0.1103	0.7135
81053	4.6	May-96	139	0	0	0	0	66.91	0.01967	0.1263	0.8172
81053	4.6	Oct-96	144	310	0	0	310	72.66	0.02167	0.1387	0.8937
81053	4.6	Nov-96	145	253	0	0	253	73.04	0.02173	0.1391	0.8972
81053	4.6	Mar-97	149	457	0	0	457	74.65	0.02205	0.1414	0.9137
91803	7.2	Jul-89	49	0	0	0	0	419	0.1179	0.7465	4.75
91803	7.2	Sep-90	63	0	0	0	0	598.3	0.1701	1.075	6.819
91803	7.2	Aug-91	74	0	0	0	0	724	0.2052	1.297	8.234
91803	7.2	Sep-92	87	8	0	0	8	904.2	0.255	1.614	10.26
91803	7.2	May-94	107	211	0	0	211	1153	0.3196	2.029	12.96
91803	7.2	May-95	119	240	0	0	240	1362	0.3778	2.398	15.31
91803	7.2	Oct-96	136	84	82	0	166	1768	0.4981	3.151	20.03
91803	7.2	May-97	143	301	0	0	301	1845	0.5135	3.257	20.77
91803	7.2	Sep-97	147	15	325	0	340	2021	0.5687	3.599	22.89
91803	7.2	Jun-98	156	195	0	0	195	2172	0.6041	3.833	24.44
120103	12	Dec-96	14	0	0	0	0	2.623	0.00045	0.00285	0.01802
120104	18	Dec-96	14	0	0	0	0	0.1084	1.3E-05	8.5E-05	0.00054
120105	7.9	Dec-96	14	0	0	0	0	43.45	0.00961	0.06155	0.3947
120106	15	Dec-96	14	0	0	0	0	0.378	5.4E-05	0.00034	0.00215
123995	5	Apr-92	197	0	0	0	0	12870	3.208	20.97	137.4
123995	5	Mar-94	220	86	0	0	86	14530	3.615	23.64	154.9
123995	5	Jan-96	242	58	0	0	58	16200	4.027	26.34	172.7
123995	5	Jan-96	243	122	0	0	122	16250	4.038	26.42	173.2
123997	3.1	Aug-90	195	0	0	0		710.6	0.2385	1.522	9.767
123997	3.1	Oct-91	209	0	0	0		796.1	0.2675	1.706	10.95
123997	3.1	Mar-93	226	0	0	0		907.8	0.3025	1.935	12.44
123997	3.1	Mar-94	238	0	0	0		991.9	0.3298	2.111	13.58
124105	2.3	Apr-89	53	0	0	0	0	4526	1.654	10.74	70.2
124105	2.3	Oct-91	83	0	0	0	0	7906	2.922	18.92	123.2
124105	2.3	Mar-93	100	0	0	0	0	9969	3.621	23.56	154.2
124106	8.2	Apr-89	21	0	0	0	0	797	0.2047	1.245	7.589
124106	8.2	Feb-91	43	0	0	0	0	1750	0.4411	2.695	16.49
124106	8.2	Jul-91	48	0	0	0	0	2017	0.5119	3.121	19.07
124106	8.2	Mar-94	80	0	0	0	0	3537	0.8799	5.393	33.11
124106	8.2	Jan-97	114	0	0	0	0	5370	1.333	8.173	50.21
124107	2.7	Dec-89	75	0	0	0	0	175.5	0.058	0.3795	2.491
124107	2.7	Feb-91	89	0	0	0	0	223	0.07278	0.478	3.149
124107	2.7	Jul-91	94	0	0	0	0	240.1	0.07853	0.5154	3.394
124107	2.7	Mar-93	114	732	355	9	1096	317.3	0.103	0.6775	4.472
124107	2.7	Mar-94	126	656	243	0	899	368.2	0.1192	0.7846	5.183
124107	2.7	Jan-96	148	264	812	93	1168	468.6	0.1513	0.9967	6.59
124107	2.7	Mar-97	162	44	372	1224	1640	539.3	0.1732	1.143	7.567

Table B-2 (Cont'd) Measured Alligator Cracking Fatigue Cracking and Predicted Bottom-up Damage Using Shell Oil Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})			
				Low	Medium	High	Total	1.0,1.1	1.1,0.9	1.1,1.0	1.1,1.1
124108	9.9	Apr-89	35	0	0	0	0	21.21	0.00479	0.02926	0.179
124108	9.9	Jan-91	56	0	0	0	0	35.57	0.00798	0.04878	0.2988
124108	9.9	Oct-91	65	0	0	0	0	44.19	0.00996	0.06085	0.3723
124108	9.9	Mar-94	94	0	0	0	0	62.75	0.01387	0.08505	0.5226
124108	9.9	Aug-94	99	0	0	0	0	70.04	0.01564	0.09566	0.5866
124108	9.9	Jan-96	116	0	0	0	0	81.57	0.018	0.1104	0.6786
124135	1.4	Dec-89	227	1112	86	0	1198	96050	41.29	272.2	1808
124135	1.4	Jan-91	240	2045	355	0	2400	101300	43.4	286.4	1903
131031	11.1	Apr-91	119	0	0	0		85.58	0.01924	0.1161	0.7027
131031	11.1	Jul-92	134	0	0	0		108.3	0.02435	0.1469	0.8887
131031	11.1	Jan-93	140	0	0	0		115.5	0.02592	0.1564	0.947
131031	11.1	Apr-94	155	0	0	0		139.7	0.03129	0.1889	1.144
131031	11.1	Oct-94	161	0	0	0		159.7	0.03613	0.2176	1.314
131031	11.1	Aug-95	171	0	0	0		177.6	0.0399	0.2406	1.456
131031	11.1	Jan-96	176	0	0	0		183.8	0.04113	0.2483	1.503
131031	11.1	Apr-96	179	0	0	0		186.7	0.04158	0.2513	1.523
134111	8.7	Mar-89	101	0	0	0	0	257.7	0.07675	0.4716	2.911
134111	8.7	Mar-91	125	0	0	0	0	394.8	0.1167	0.7187	4.446
134111	8.7	Feb-92	136	316	0	0	316	469.2	0.1392	0.8563	5.292
134112	15.9	May-89	144	0	0	0	0	123	0.03229	0.1866	1.082
134112	15.9	Feb-91	165	0	0	0	0	153.9	0.04013	0.2323	1.349
134112	15.9	Apr-91	167	0	0	0	0	155.9	0.04049	0.2346	1.364
134112	15.9	Feb-94	201	0	0	0	0	216.3	0.05672	0.3278	1.9
134112	15.9	Oct-94	209	0	0	0	0	236.3	0.06202	0.3584	2.078
134112	15.9	Jan-96	224	0	0	0	0	260.6	0.06787	0.393	2.282
134112	15.9	Feb-97	237	0	0	0	0	287.6	0.07517	0.4347	2.522
134112	15.9	Apr-98	251	0	0	0	0	314.2	0.08161	0.4727	2.747
134113	15.2	May-89	144	0	0	0	0	584.1	0.1716	0.9811	5.626
134113	15.2	Feb-91	165	0	0	0	0	709.8	0.2073	1.187	6.818
134113	15.2	Apr-91	167	0	0	0	0	717.5	0.2089	1.197	6.88
134113	15.2	Feb-94	201	0	0	0	0	956.3	0.2807	1.605	9.203
134113	15.2	Oct-94	209	0	0	0	0	1034	0.3038	1.737	9.96
134113	15.2	Jan-96	224	0	0	0	0	1127	0.3288	1.883	10.82
134113	15.2	Feb-97	237	47	0	0	47	1230	0.3599	2.059	11.82
134113	15.2	Apr-98	251	44	0	0	44	1330	0.3872	2.218	12.74
161001	3.7	Jul-89	192	0	0	0	0	324.5	0.06592	0.4643	3.304
161001	3.7	Aug-90	205	0	0	0	0	360.5	0.07333	0.5161	3.67
161001	3.7	Jun-93	239	36	0	0	36	452.4	0.09055	0.6396	4.565
161001	3.7	Aug-94	253	16	0	0	16	501.8	0.1011	0.7128	5.078
161001	3.7	May-95	262	0	0	0	0	523.6	0.1044	0.7378	5.27
161001	3.7	Jul-97	288	3	611	0	615	617.2	0.1232	0.8706	6.215
161001	3.7	Sep-98	302	0	434	99	533	672.1	0.1344	0.9496	6.774
161009	10.4	Sep-89	180	0	0	0		18.76	0.0033	0.02087	0.1325
161009	10.4	Jul-90	190	0	0	0		20.14	0.00354	0.02238	0.1421
161009	10.4	Jul-92	214	0	0	0		24.25	0.00424	0.02686	0.1707

Table B-2 (Cont'd) Measured Alligator Cracking Fatigue Cracking and Predicted Bottom-up Damage Using Shell Oil Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})			
				Low	Medium	High	Total	1.0,1.1	1.1,0.9	1.1,1.0	1.1,1.1
161009	10.4	Oct-93	229	0	0	0		27.79	0.00488	0.03086	0.196
161009	10.4	Jun-96	261	0	0	0		34.34	0.00599	0.03798	0.2415
161009	10.4	Jul-97	274	0	0	0		38.13	0.00667	0.04225	0.2686
161021	5.9	Sep-89	48	0	0	0	0	9.719	0.00249	0.01556	0.09788
161021	5.9	Oct-90	61	0	0	0	0	12.26	0.00312	0.01954	0.123
161021	5.9	Aug-91	71	0	0	0	0	14.06	0.0036	0.02251	0.1415
161021	5.9	Aug-93	95	0	0	0	0	19.04	0.00485	0.03032	0.1909
161021	5.9	Sep-95	120	0	0	0	0	24.3	0.0062	0.03874	0.2438
161021	5.9	Jun-96	129	0	0	0	0	25.42	0.00644	0.04031	0.2541
161021	5.9	Jul-97	142	0	0	0	0	28.5	0.00723	0.04526	0.2851
169034	9.2	Jul-89	10	0	0	0	0	3.469	0.00067	0.00429	0.0276
169034	9.2	Aug-90	23	0	0	0	0	10.22	0.00219	0.01364	0.08549
169034	9.2	Jun-93	57	0	0	0	0	22.07	0.00458	0.02877	0.1816
169034	9.2	Aug-94	71	0	0	0	0	29.6	0.00629	0.03932	0.2467
169034	9.2	May-95	80	0	0	0	0	31.13	0.00654	0.04095	0.2577
169034	9.2	Jul-97	106	25	0	0	25	42.71	0.00903	0.05648	0.3548
169034	9.2	Sep-98	120	0	0	25	25	49.44	0.01049	0.06556	0.4115
201009	11.1	Aug-88	44	10	0	0	10	2.851	0.00059	0.00357	0.02181
201009	11.1	May-89	53	0	0	0	0	3.113	0.00063	0.00385	0.02362
201009	11.1	Dec-90	72	42	0	0	42	4.579	0.00094	0.00573	0.03496
201009	11.1	Oct-91	82	1	13	0	14	5.298	0.00108	0.0066	0.04033
201009	11.1	Apr-93	100	6	18	16	41	6.264	0.00128	0.00782	0.04773
201009	11.1	Apr-95	124	2	54	0	56	7.739	0.00157	0.0096	0.05867
201009	11.1	Apr-96	136	0	0	0	0	8.484	0.00172	0.0105	0.06422
201009	11.1	Jan-99	168	0	1643	0	1643	11.03	0.00224	0.01366	0.08349
251003	6.6	Aug-89	180	0	0	0	0	1302	0.3478	2.241	14.51
251003	6.6	Sep-90	193	0	0	0	0	1423	0.3788	2.443	15.83
251003	6.6	Aug-91	204	28	0	0	28	1521	0.4045	2.61	16.92
251003	6.6	Sep-92	217	56	93	0	149	1670	0.446	2.874	18.61
251003	6.6	Oct-95	254	45	75	0	121	2038	0.5407	3.49	22.63
251003	6.6	Oct-96	266	1314	0	0	1314	2171	0.5756	3.715	24.1
251003	6.6	Jun-98	286	1062	62	0	1125	2384	0.6316	4.077	26.45
251004	9.6	Aug-89	178	0	0	0	0	615	0.1746	1.101	6.956
251004	9.6	Sep-90	191	0	0	0	0	693.3	0.1967	1.24	7.839
251004	9.6	Aug-91	202	0	0	0	0	751.2	0.2132	1.344	8.495
251004	9.6	Sep-92	215	0	0	0	0	832.1	0.2355	1.486	9.393
251004	9.6	Oct-95	252	0	0	0	0	1099	0.3112	1.963	12.41
251004	9.6	Jun-97	272	56	0	0	56	1223	0.3445	2.175	13.76
251004	9.6	Jun-98	284	0	0	0	0	1336	0.3766	2.377	15.04
261001	2.2	Jul-88	203	0	0	0	0	35.42	0.00906	0.06493	0.4694
261001	2.2	Sep-89	217	0	0	0	0	37.82	0.00971	0.0695	0.5019
261001	2.2	Jul-90	227	0	0	0	0	39.41	0.01008	0.07221	0.522
261001	2.2	Jul-91	239	33	0	0	33	41.63	0.01064	0.07628	0.5515
261001	2.2	Sep-91	241	28	0	0	28	42.04	0.01076	0.07711	0.5572
261001	2.2	Sep-92	253	40	0	0	40	44.04	0.01124	0.08059	0.5829

Table B-2 (Cont'd) Measured Alligator Cracking Fatigue Cracking and Predicted Bottom-up Damage Using Shell Oil Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})			
				Low	Medium	High	Total	1.0,1.1	1.1,0.9	1.1,1.0	1.1,1.1
261001	2.2	Jun-93	262	0	81	0	81	45.64	0.01162	0.08339	0.6036
261001	2.2	Jun-93	263	76	0	0	76	45.85	0.01169	0.08387	0.6068
261001	2.2	May-95	285	58	0	0	58	49.41	0.01257	0.09023	0.6531
261001	2.2	Jul-96	299	83	0	0	83	52.06	0.01327	0.09521	0.6888
261004	4.2	Sep-89	51	0	0	0	0	31.29	0.01127	0.07094	0.449
261004	4.2	Jul-90	61	0	0	0	0	36.61	0.01305	0.08233	0.5227
271018	4.4	Apr-89	124	0	0	0	0	396.2	0.1044	0.6828	4.486
271018	4.4	Jun-89	126	0	0	0	0	413.6	0.1091	0.7137	4.689
271018	4.4	Oct-90	142	0	0	0	0	490	0.1296	0.847	5.558
271018	4.4	Jun-93	174	0	0	0	0	642.7	0.1698	1.109	7.284
271018	4.4	Jul-93	176	0	0	0	0	662	0.1754	1.145	7.513
271018	4.4	Mar-94	183	0	0	0	0	676.8	0.1783	1.165	7.654
271018	4.4	Aug-94	188	0	0	0	0	729.8	0.1929	1.26	8.269
271087	15.7	Oct-91	154	0	0	0		0.1784	2.2E-05	0.00014	0.0009
271087	15.7	May-93	173	0	0	0		0.192	2.4E-05	0.00015	0.00097
271087	15.7	Oct-94	190	0	0	0		0.216	2.7E-05	0.00017	0.00109
271087	15.7	Jun-96	210	0	0	0		0.2335	2.9E-05	0.00019	0.00118
291008	11.4	Feb-92	70	41	0	0	41	5.801	0.00107	0.00664	0.04116
291008	11.4	Mar-93	83	140	22	0	161	7.005	0.0013	0.00803	0.04975
291008	11.4	Mar-93	83	0	0	0	0	0	0	0	0
291008	11.4	Apr-96	120	0	0	0	0	11.15	0.00207	0.01278	0.07927
291008	11.4	Feb-00	152	365	715	0	1080	15.61	0.0029	0.01794	0.1112
307088	4.9	Sep-89	100	0	0	0	0	48.53	0.01364	0.08856	0.5793
307088	4.9	May-91	120	0	66	0	66	54.17	0.01494	0.09729	0.6387
308129	3.2	Oct-89	17	0	0	0	0	16.7	0.00534	0.0348	0.2287
308129	3.2	Jul-91	38	0	0	0	0	32.2	0.0095	0.06294	0.421
308129	3.2	Jul-92	50	0	0	0	0	40.87	0.01184	0.07871	0.5283
308129	3.2	Aug-93	63	0	0	0	0	50.52	0.0145	0.09647	0.6483
308129	3.2	Dec-93	67	0	0	0	0	53.18	0.01509	0.1007	0.6783
308129	3.2	Mar-94	70	0	0	0	0	54.92	0.01539	0.1029	0.696
308129	3.2	Oct-94	77	0	0	0	0	62.3	0.01775	0.1182	0.7957
308129	3.2	Feb-95	81	0	0	0	0	64.66	0.01815	0.1213	0.8199
308129	3.2	May-95	84	0	0	0	0	68.03	0.01904	0.1274	0.8621
308129	3.2	Jun-96	97	0	0	0	0	79.03	0.02199	0.1473	0.9976
308129	3.2	Oct-96	101	0	0	0	0	82.78	0.0232	0.1551	1.048
308129	3.2	Jan-97	104	0	0	0	0	84.62	0.02351	0.1575	1.066
308129	3.2	Mar-97	106	0	0	0	0	86.11	0.02377	0.1595	1.082
308129	3.2	Aug-97	111	0	0	0	0	92.65	0.02594	0.1734	1.172
308129	3.2	Oct-97	113	0	0	0	0	94.53	0.02645	0.1769	1.195
321020	7	Jul-91	86	0	0	0	0	103.9	0.02316	0.1487	0.9582
321020	7	Aug-93	111	18	0	0	18	146.8	0.03276	0.2102	1.354
321020	7	Sep-94	123	187	62	0	250	166.6	0.03712	0.2382	1.534
321020	7	Apr-95	131	34	0	0	34	175.3	0.03869	0.2488	1.607
321020	7	Jun-97	157	672	1043	0	1715	226.4	0.04998	0.3213	2.074
321020	7	Jun-98	169	3269	36	0	3305	252.4	0.05565	0.3579	2.311

Table B-2 (Cont'd) Measured Alligator Cracking Fatigue Cracking and Predicted Bottom-up Damage Using Shell Oil Model.											
Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})			
				Low	Medium	High	Total	1.0,1.1	1.1,0.9	1.1,1.0	1.1,1.1
341031	7.3	Apr-92	224	280	12	0	292	703.9	0.2464	1.515	9.345
341031	7.3	Feb-93	234	598	11	0	609	778.3	0.2727	1.677	10.34
341031	7.3	Oct-95	266	0	652	305	957	1054	0.3681	2.266	13.98
341031	7.3	Nov-95	267	574	8	0	581	1055	0.3683	2.267	13.99
341033	7.4	Apr-92	211	79	0	0	79	142.6	0.03831	0.2392	1.498
341033	7.4	Feb-93	221	6	0	0	6	151	0.04051	0.253	1.585
341033	7.4	Nov-95	254	15	0	0	15	180.6	0.0486	0.3033	1.899
341033	7.4	Jul-97	274	0	0	0	0	196.3	0.05275	0.3293	2.063
341034	11.1	Oct-89	48	0	0	0	0	14.63	0.00227	0.01463	0.09458
341034	11.1	Sep-90	59	0	0	0	0	18.55	0.00288	0.01854	0.1199
341034	11.1	Apr-92	78	0	0	0	0	23.46	0.00361	0.02329	0.1507
341034	11.1	Feb-93	88	0	0	0	0	27.49	0.00423	0.0273	0.1766
341034	11.1	Nov-95	121	0	0	0	0	42.28	0.00652	0.04205	0.2719
341034	11.1	Jul-97	141	129	75	0	205	51.14	0.0079	0.05091	0.329
350101	7.2	May-97	19	0	0	0	0	1959	0.6325	3.898	24.11
350102	4.8	May-97	19	0	0	0	0	1602	0.5313	3.394	21.82
350103	12.5	May-97	19	0	0	0	0	3116	0.8942	5.41	32.8
350104	19.2	May-97	19	0	0	0	0	124.4	0.02669	0.1605	0.9667
350105	9.9	May-97	19	0	0	0	0	39550	13.37	79.89	478.5
350106	15.6	May-97	19	0	0	0	0	535.1	0.1328	0.7956	4.777
351005	8.9	Oct-89	73	0	0	0	0	95.5	0.02448	0.1532	0.9614
351005	8.9	Mar-91	90	0	0	0	0	128.1	0.0332	0.2073	1.297
351005	8.9	Oct-92	109	0	0	0	0	176.5	0.04525	0.2833	1.778
351005	8.9	Feb-94	125	0	0	0	0	214.6	0.0552	0.3453	2.165
351005	8.9	Mar-95	138	0	0	0	0	252.1	0.06448	0.4038	2.535
351005	8.9	Apr-97	163	0	0	0	0	341.6	0.0874	0.5473	3.436
351022	6.3	Oct-89	37	0	0	0	0	71.82	0.01957	0.1242	0.7917
351022	6.3	Mar-91	54	0	0	0	0	101	0.02663	0.17	1.091
351022	6.3	Oct-92	73	0	0	0	0	165.5	0.04444	0.2821	1.799
351022	6.3	Feb-94	89	0	0	0	0	205.6	0.05434	0.346	2.215
351022	6.3	Mar-95	102	0	0	0	0	251.5	0.06648	0.4229	2.705
351022	6.3	Apr-97	127	0	0	0	0	347.3	0.09108	0.5801	3.715
351112	6.3	Dec-89	67	0	0	0	0	441.4	0.1376	0.8412	5.16
351112	6.3	Jan-91	80	0	0	0	0	514	0.1588	0.9725	5.976
351112	6.3	Mar-91	82	0	0	0	0	516.6	0.1592	0.9755	5.997
351112	6.3	Jan-93	104	0	0	0	0	674.1	0.2071	1.27	7.808
351112	6.3	Feb-94	117	0	0	0	0	748.4	0.2287	1.403	8.64
351112	6.3	Oct-94	125	0	0	0	0	818.7	0.2497	1.533	9.444
351112	6.3	Mar-95	130	9	0	0	9	826.7	0.2511	1.543	9.51
351112	6.3	Apr-95	131	0	0	0	0	829.5	0.2516	1.547	9.536
351112	6.3	Jun-95	133	0	0	0	0	849.8	0.2576	1.584	9.767
351112	6.3	Nov-96	150	0	0	0	0	980.4	0.2982	1.831	11.28
351112	6.3	Apr-97	155	0	0	0	0	991.4	0.3003	1.846	11.38
351112	6.3	Sep-97	160	0	0	0	0	1050	0.3188	1.959	12.07
371024	4.8	Nov-89	109	167	0	0	167	8.899	0.00267	0.01698	0.1087

Table B-2 (Cont'd) Measured Alligator Cracking Fatigue Cracking and Predicted Bottom-up Damage Using Shell Oil Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})			
				Low	Medium	High	Total	1.0,1.1	1.1,0.9	1.1,1.0	1.1,1.1
371024	4.8	Mar-91	125	889	89	0	978	10.21	0.00303	0.01928	0.1237
371024	4.8	Apr-92	138	1442	308	342	2093	11.61	0.00343	0.02186	0.1404
371802	4.5	Mar-91	66	36	0	0	36	2306	1.167	7.1	43.46
371802	4.5	Oct-92	85	51	36	0	86	3120	1.597	9.691	59.17
371802	4.5	Apr-94	103	1521	0	0	1521	3748	1.895	11.53	70.62
371802	4.5	Jul-95	118	1739	70	0	1809	4395	2.233	13.57	83.02
371802	4.5	Apr-96	127	2608	206	0	2814	4717	2.383	14.51	88.85
371992	2.4	Mar-91	14	0	0	0	0	77.94	0.02477	0.1685	1.154
371992	2.4	Oct-92	33	2	0	0	2	212.4	0.07239	0.4824	3.238
371992	2.4	Apr-94	51	0	0	0	0	359.5	0.1152	0.7804	5.328
371992	2.4	Feb-96	73	0	0	0	0	579.6	0.1873	1.265	8.614
404087	10.1	Jan-90	43	0	0	0	0	55.46	0.01923	0.1135	0.6711
404087	10.1	Oct-91	64	0	0	0	0	96.31	0.0337	0.1983	1.17
404087	10.1	Nov-92	77	0	0	0	0	115	0.03961	0.2339	1.385
404087	10.1	Feb-93	80	0	0	0	0	115.3	0.03964	0.2342	1.387
404087	10.1	Nov-94	101	0	0	0	0	167.9	0.05803	0.3423	2.025
404087	10.1	Feb-95	104	32	0	0	32	168.3	0.05806	0.3426	2.027
404087	10.1	Aug-95	110	0	0	0	0	186	0.0639	0.3775	2.236
404087	10.1	Jun-97	132	67	207	0	273	230.6	0.07821	0.4633	2.752
404163	11.5	Jan-90	34	0	0	0	0	304.4	0.08869	0.5279	3.148
404163	11.5	Mar-91	48	0	0	0	0	389.7	0.1114	0.6656	3.984
404163	11.5	Oct-91	55	0	0	0	0	514.9	0.15	0.8923	5.317
404163	11.5	Nov-92	68	0	0	0	0	611.4	0.1766	1.052	6.278
404163	11.5	Mar-93	72	0	0	0	0	613.7	0.1769	1.054	6.292
404163	11.5	Nov-94	92	0	0	0	0	828.1	0.2391	1.424	8.494
404163	11.5	Apr-96	109	27	0	0	27	932.2	0.2674	1.594	9.522
404163	11.5	Aug-97	125	0	0	0	0	1098	0.3136	1.871	11.19
404163	11.5	Jan-99	141	13	0	0	13	1203	0.3408	2.037	12.19
404165	8.1	Jan-90	68	0	0	0	0	487.9	0.1265	0.7735	4.742
404165	8.1	Mar-91	82	0	0	0	0	572.3	0.1466	0.8991	5.528
404165	8.1	Oct-91	89	0	0	0	0	679.7	0.1765	1.079	6.613
404165	8.1	Nov-92	102	0	0	0	0	776.4	0.2003	1.226	7.526
404165	8.1	Mar-93	106	0	0	0	0	780.3	0.2007	1.229	7.55
404165	8.1	Oct-94	125	1	2	0	3	960.1	0.2455	1.506	9.26
404165	8.1	Nov-94	126	0	0	0	0	963.1	0.2459	1.509	9.282
404165	8.1	Apr-95	131	3	0	0	3	970	0.2468	1.515	9.327
404165	8.1	Jun-95	133	3	0	0	3	996	0.2528	1.553	9.568
404165	8.1	Apr-96	143	0	0	0	0	1062	0.2687	1.652	10.18
404165	8.1	Nov-96	150	0	0	0	0	1178	0.3012	1.847	11.36
404165	8.1	May-97	156	32	0	0	32	1197	0.3044	1.869	11.51
404165	8.1	Sep-97	160	40	0	0	40	1275	0.3259	1.999	12.29
421599	12.3	Aug-89	25	0	0	0	0	14.79	0.00316	0.01896	0.1141
421599	12.3	Sep-90	38	0	0	0	0	22.13	0.00464	0.02794	0.1688
421599	12.3	Mar-93	68	0	0	0	0	39.59	0.00829	0.04994	0.3017
421599	12.3	Sep-94	86	0	0	0	0	55.85	0.01173	0.07064	0.4264

Table B-2 (Cont'd) Measured Alligator Cracking Fatigue Cracking and Predicted Bottom-up Damage Using Shell Oil Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})			
				Low	Medium	High	Total	1.0,1.1	1.1,0.9	1.1,1.0	1.1,1.1
421599	12.3	Jun-95	95	0	0	0	0	60.71	0.01271	0.07659	0.4628
421599	12.3	Jul-96	108	0	0	0	0	72.61	0.01526	0.09188	0.5546
421599	12.3	Mar-98	128	9	0	0	9	88.29	0.01848	0.1113	0.6724
451011	3.2	Mar-92	69	0	0	0	0	415	0.1286	0.8248	5.328
451011	3.2	Oct-92	76	0	0	0	0	466.6	0.1474	0.9411	6.047
451011	3.2	Jun-93	84	1101	0	0	1101	516	0.161	1.031	6.649
451011	3.2	Jan-96	115	11	46	0	57	711.7	0.2206	1.415	9.14
451011	3.2	Jun-97	132	1729	41	150	1919	821.7	0.2537	1.629	10.53
451011	3.2	Feb-99	150	1203	612	254	2070	945.1	0.2928	1.879	12.14
473104	1.3	Aug-89	39	0	74	0	74	79.57	0.03751	0.2565	1.771
473104	1.3	Nov-89	42	0	0	0	0	80.84	0.03786	0.2591	1.79
473104	1.3	May-91	60	52	0	0	52	89.2	0.04008	0.276	1.919
473104	1.3	Aug-91	63	451	0	0	451	89.39	0.04015	0.2764	1.922
473104	1.3	Oct-92	77	140	19	0	159	95.63	0.0419	0.2895	2.02
473104	1.3	Aug-93	87	370	0	0	370	101.3	0.04337	0.3007	2.106
473104	1.3	Nov-95	114	124	300	292	716	119.7	0.04856	0.3399	2.402
473104	1.3	Oct-96	125	159	1217	407	1784	127.1	0.05062	0.3554	2.52
480001	2.4	Apr-89	1	0	0	0	0	34.74	0.01887	0.1131	0.6805
480001	2.4	Oct-90	19	0	0	0	0	725.5	0.4158	2.438	14.39
480001	2.4	May-91	26	0	0	0	0	1078	0.5767	3.449	20.77
480001	2.4	Feb-93	47	0	0	0	0	2269	1.201	7.19	43.38
480001	2.4	Apr-93	49	0	0	0	0	2410	1.27	7.615	46.01
480001	2.4	Feb-95	71	0	0	0	0	4055	2.136	12.81	77.41
480001	2.4	Mar-95	72	0	0	0	0	4140	2.174	13.05	78.93
480001	2.4	May-97	98	0	18	0	18	6602	3.435	20.68	125.4
480001	2.4	Mar-98	108	0	27	0	27	7661	3.983	23.97	145.4
481060	7.5	Jun-90	52	0	0	0		18180	5.206	31.82	195
481060	7.5	Feb-91	60	0	0	0	0	22220	6.36	38.87	238.1
481060	7.5	Apr-91	62	0	0	0	0	23030	6.537	40.02	245.7
481060	7.5	Mar-92	73	0	0	0	0	29600	8.427	51.56	316.3
481060	7.5	Feb-93	84	8	0	0	8	36710	10.43	63.83	391.7
481060	7.5	Mar-93	85	0	0	0	0	36990	10.48	64.19	394.1
481060	7.5	Oct-94	104	0	0	0	0	54270	15.43	94.47	579.7
481060	7.5	Feb-95	108	0	0	0	0	55180	15.59	95.58	587.2
481060	7.5	Mar-95	109	0	0	0	0	55530	15.66	96	590.1
481060	7.5	Mar-95	112	0	0	0	0	58410	16.42	100.8	620
481060	7.5	Jun-95	134	0	0	0	0	77590	21.74	133.5	821.7
481060	7.5	Apr-97	137	0	0	0	0	82420	23.18	142.2	874.7
481060	7.5	Jul-97	139	12	0	0	12	86130	24.34	149.2	916.5
481060	7.5	Sep-97	154	0	0	0	0	101100	28.37	174.1	1072
481077	5.1	Apr-89	88	0	0	0	0	302.4	0.07668	0.4817	3.049
481077	5.1	Nov-91	119	0	0	0	0	432.4	0.1107	0.6935	4.377
481077	5.1	Oct-92	130	0	0	0	0	479.9	0.1227	0.7691	4.855
481077	5.1	May-93	137	0	0	0	0	501.1	0.1265	0.7951	5.036
481077	5.1	Oct-94	154	10	0	0	10	583.2	0.1491	0.9339	5.895

Table B-2 (Cont'd) Measured Alligator Cracking Fatigue Cracking and Predicted Bottom-up Damage Using Shell Oil Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})			
				Low	Medium	High	Total	1.0,1.1	1.1,0.9	1.1,1.0	1.1,1.1
481077	5.1	Mar-95	159	0	0	0	0	595.7	0.1508	0.947	5.991
481077	5.1	Apr-95	160	0	0	0	0	600.4	0.1519	0.9537	6.036
481077	5.1	Jun-95	162	0	0	0	0	612.4	0.1551	0.9737	6.161
481077	5.1	Aug-95	164	0	0	0	0	625.8	0.1596	1	6.316
481077	5.1	Jun-96	174	0	0	0	0	666.3	0.1683	1.057	6.694
481077	5.1	May-97	185	13	0	0	13	714.9	0.1799	1.131	7.17
481077	5.1	Jul-97	187	56	0	0	56	728.6	0.1841	1.157	7.322
481077	5.1	Sep-97	189	50	0	0	50	742.2	0.1884	1.182	7.475
481077	5.1	Mar-98	195	41	0	0	41	761.6	0.1916	1.205	7.635
481109	6.5	Jan-90	68	0	0	0	0	1238	1.039	5.153	25.64
481109	6.5	Sep-90	76	0	0	0	0	1435	1.21	5.997	29.8
481109	6.5	May-91	84	0	0	0	0	1587	1.318	6.56	32.73
481109	6.5	Feb-93	105	73	0	0	73	2079	1.713	8.542	42.7
481109	6.5	Jul-93	110	0	0	0	0	2225	1.841	9.168	45.79
481109	6.5	Feb-95	129	186	0	0	186	2695	2.2	11	55.1
481109	6.5	May-95	132	74	0	0	74	2784	2.272	11.36	56.92
481109	6.5	Aug-96	147	150	0	0	150	3230	2.642	13.2	66.1
481169	1.1	Feb-90	211	0	0	0	0	3052	1.441	8.773	53.7
481169	1.1	Mar-90	212	0	0	0	0	3068	1.45	8.823	53.99
481169	1.1	Sep-90	218	0	0	0	0	3099	1.468	8.924	54.55
481169	1.1	Jan-91	222	0	0	0	0	3240	1.53	9.313	57.01
481169	1.1	Mar-91	224	0	0	0	0	3288	1.553	9.452	57.85
481169	1.1	Jun-91	227	0	0	0	0	3305	1.563	9.507	58.16
481169	1.1	Jan-92	234	0	0	0	0	3465	1.636	9.957	60.96
481169	1.1	Feb-93	247	0	0	0	0	3724	1.757	10.7	65.51
481169	1.1	Aug-93	253	0	0	0	0	3765	1.78	10.83	66.25
481169	1.1	Mar-95	272	0	0	0	0	4199	1.981	12.06	73.86
481169	1.1	Jul-95	276	0	0	0	0	4221	1.994	12.13	74.26
481169	1.1	Jul-97	300	0	0	0	0	4700	2.219	13.51	82.67
481174	4.7	Oct-90	186	0	0	0	0	218	0.07442	0.4531	2.771
481174	4.7	Feb-91	190	0	0	0	0	220.6	0.07497	0.4569	2.798
481174	4.7	Apr-91	192	0	16	0	16	222.7	0.07555	0.4607	2.822
481174	4.7	Mar-92	203	0	0	0	0	236.3	0.08009	0.4885	2.993
481174	4.7	Feb-93	214	22	0	0	22	249.7	0.08465	0.5162	3.163
481174	4.7	Mar-93	215	58	0	0	58	250.6	0.08488	0.5178	3.174
481174	4.7	Feb-95	238	28	0	0	28	278.4	0.09426	0.5751	3.525
481174	4.7	Mar-95	239	109	0	0	109	279.3	0.09449	0.5766	3.535
481174	4.7	Jan-96	249	154	0	0	154	291.6	0.09876	0.6025	3.693
481174	4.7	Apr-97	264	492	6	0	498	309.4	0.1044	0.6377	3.912
481174	4.7	Mar-98	275	422	61	0	483	322.5	0.1089	0.6646	4.077
481178	8.5	Feb-91	32	0	0	0	0	14	0.00481	0.02746	0.1572
481178	8.5	May-91	33	0	0	0	0	14.31	0.00489	0.02793	0.1602
481178	8.5	Feb-93	56	0	0	0	0	26.69	0.0091	0.05207	0.2989
481178	8.5	Jul-93	61	0	0	0	0	30.22	0.01027	0.05885	0.3382
481178	8.5	Feb-95	80	9	0	0	9	41.73	0.01411	0.08094	0.4657

Table B-2 (Cont'd) Measured Alligator Cracking Fatigue Cracking and Predicted Bottom-up Damage Using Shell Oil Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})			
				Low	Medium	High	Total	1.0,1.1	1.1,0.9	1.1,1.0	1.1,1.1
481178	8.5	Mar-95	81	9	0	0	9	42.01	0.01417	0.08132	0.4682
481183	5.7	Sep-90	188	0	0	0		709.4	0.393	2.287	13.37
481183	5.7	Mar-91	194	0	0	0		726	0.3989	2.326	13.61
481183	5.7	Oct-91	201	0	0	0		817	0.4497	2.622	15.34
481183	5.7	Nov-91	202	0	0	0		818.1	0.4499	2.623	15.35
481183	5.7	Jan-93	216	0	0	0		953.3	0.5289	3.077	17.97
481183	5.7	Jul-93	222	0	0	0		1021	0.5643	3.285	19.21
481183	5.7	Apr-94	231	0	0	0		1096	0.6022	3.51	20.54
483749	1.8	Oct-90	116	0	0	0	0	3329	1.475	9.762	65.04
483749	1.8	Apr-91	122	0	0	0	0	3531	1.547	10.27	68.62
483749	1.8	Aug-91	126	0	0	0	0	3622	1.592	10.56	70.46
483749	1.8	Mar-92	133	0	0	0	0	3845	1.673	11.12	74.43
483749	1.8	Feb-93	144	55	132	41	228	4153	1.8	11.97	80.19
483749	1.8	Mar-93	145	47	75	0	123	4187	1.811	12.05	80.78
483749	1.8	Feb-95	168	210	172	177	559	4856	2.083	13.89	93.26
483749	1.8	Mar-95	169	41	1045	0	1086	4890	2.096	13.98	93.87
483749	1.8	Mar-97	193	115	343	1504	1962	5586	2.377	15.88	106.8
489005	1.2	Oct-90	50	126	0	0	126	12630	7.49	47	296.9
489005	1.2	Mar-91	55	19	0	0	19	15430	8.946	56.59	360.3
489005	1.2	Aug-91	60	75	0	0	75	16080	9.42	59.32	376.1
489005	1.2	Feb-93	78	24	0	0	24	23350	13.44	85.2	543.5
489005	1.2	Apr-93	80	58	0	0	58	24090	13.9	88.03	561.3
489005	1.2	Feb-95	102	0	0	0	0	31770	18.22	115.6	738.2
489005	1.2	Feb-96	114	165	0	0	165	36190	20.68	131.3	839.6
489005	1.2	Jul-96	119	202	0	0	202	37310	21.41	135.7	866.5
489005	1.2	Jul-97	131	140	0	0	140	41560	23.87	151.3	965.3
489005	1.2	Jul-98	143	110	0	0	110	46420	26.56	168.5	1077
501002	8.5	Aug-89	58	0	0	0	0	18.66	0.0047	0.02921	0.1819
501002	8.5	Aug-90	70	0	0	0	0	22.43	0.00564	0.03503	0.2183
501002	8.5	May-94	115	795	0	0	795	37.01	0.00921	0.05737	0.3584
501002	8.5	Aug-94	118	306	0	0	306	39.86	0.01003	0.06228	0.3881
501002	8.5	Apr-95	126	692	0	0	692	40.97	0.01024	0.0637	0.3974
501002	8.5	Oct-96	144	41	301	0	342	49.55	0.01239	0.07708	0.4809
501002	8.5	May-97	151	121	31	0	152	50.61	0.01261	0.0785	0.4902
501002	8.5	Oct-97	156	667	121	0	788	54.49	0.01367	0.08497	0.5297
501002	8.5	Jun-98	164	85	632	0	717	56.27	0.01408	0.08753	0.546
501004	8	Apr-93	102	0	0	0		137.1	0.03925	0.2433	1.513
501004	8	Oct-95	132	0	0	0		257.8	0.076	0.4694	2.908
501004	8	Nov-97	157	0	0	0		295.8	0.08473	0.5247	3.259
511002	5.7	Apr-89	115	127	229	30	386	1117	0.3884	2.443	15.43
511023	10.1	Oct-89	107	0	0	0	0	220	0.0577	0.3506	2.136
511023	10.1	Mar-91	124	0	0	0	0	246	0.06392	0.3892	2.375
511023	10.1	May-92	138	0	0	0	0	278.3	0.07218	0.4396	2.684
511023	10.1	Oct-92	143	13	0	0	13	299.6	0.07778	0.4737	2.892
511023	10.1	Dec-93	157	11	0	0	11	335.7	0.08735	0.5317	3.244

Table B-2 (Cont'd) Measured Alligator Cracking Fatigue Cracking and Predicted Bottom-up Damage Using Shell Oil Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})			
				Low	Medium	High	Total	1.0,1.1	1.1,0.9	1.1,1.0	1.1,1.1
511023	10.1	Sep-95	178	61	0	0	61	394.5	0.1025	0.6242	3.809
511023	10.1	Feb-96	183	182	0	0	182	397.6	0.103	0.6276	3.833
511023	10.1	Mar-97	196	276	0	0	276	432	0.112	0.6822	4.165
512021	7.5	Oct-89	54	0	0	0	0	139.7	0.03604	0.2255	1.416
512021	7.5	Mar-91	71	31	0	0	31	181.4	0.0468	0.2926	1.835
512021	7.5	Oct-92	90	0	0	0	0	245	0.06293	0.394	2.475
531008	3.4	Jul-91	153	11	17	5	33	42.45	0.01082	0.07289	0.4968
531008	3.4	Jun-93	176	25	24	6	55	49.51	0.01254	0.08464	0.5778
531008	3.4	Jun-94	188	135	439	414	988	53.41	0.01352	0.09124	0.6229
561007	2.8	Jul-90	121	0	0	0	0	25.5	0.00743	0.05004	0.3403
561007	2.8	May-91	131	0	0	0	0	27.58	0.008	0.05391	0.3672
561007	2.8	Aug-91	134	0	0	0	0	28.37	0.00827	0.0557	0.3787
561007	2.8	Aug-93	158	0	0	0	0	33.33	0.0097	0.06533	0.4444
561007	2.8	Oct-93	160	0	0	0	0	33.78	0.00983	0.06618	0.4502
561007	2.8	Dec-93	162	5	0	0	5	34.07	0.00988	0.0666	0.4534
561007	2.8	Mar-94	165	8	0	0	8	34.54	0.00998	0.06734	0.459
561007	2.8	Apr-94	166	0	0	0	0	34.88	0.01008	0.06802	0.4636
561007	2.8	Aug-94	170	6	0	0	6	35.92	0.01043	0.07028	0.4784
561007	2.8	Feb-95	176	0	0	0	0	36.48	0.01056	0.07121	0.4851
561007	2.8	May-95	179	0	0	0	0	37.3	0.01077	0.0727	0.4956
561007	2.8	Sep-95	183	0	0	0	0	38.28	0.01115	0.07505	0.5103
561007	2.8	Jun-96	192	12	0	0	12	40.09	0.01161	0.0783	0.5333
561007	2.8	Oct-96	196	0	0	0	0	41.03	0.01191	0.08024	0.5461
561007	2.8	Nov-96	197	0	0	0	0	41.17	0.01193	0.08042	0.5475
561007	2.8	Mar-97	201	0	0	0	0	41.29	0.01196	0.08059	0.5489
561007	2.8	Aug-97	206	0	0	0	0	42.92	0.01246	0.08398	0.5716
561007	2.8	Sep-97	207	0	0	0	0	43.16	0.01255	0.0845	0.575

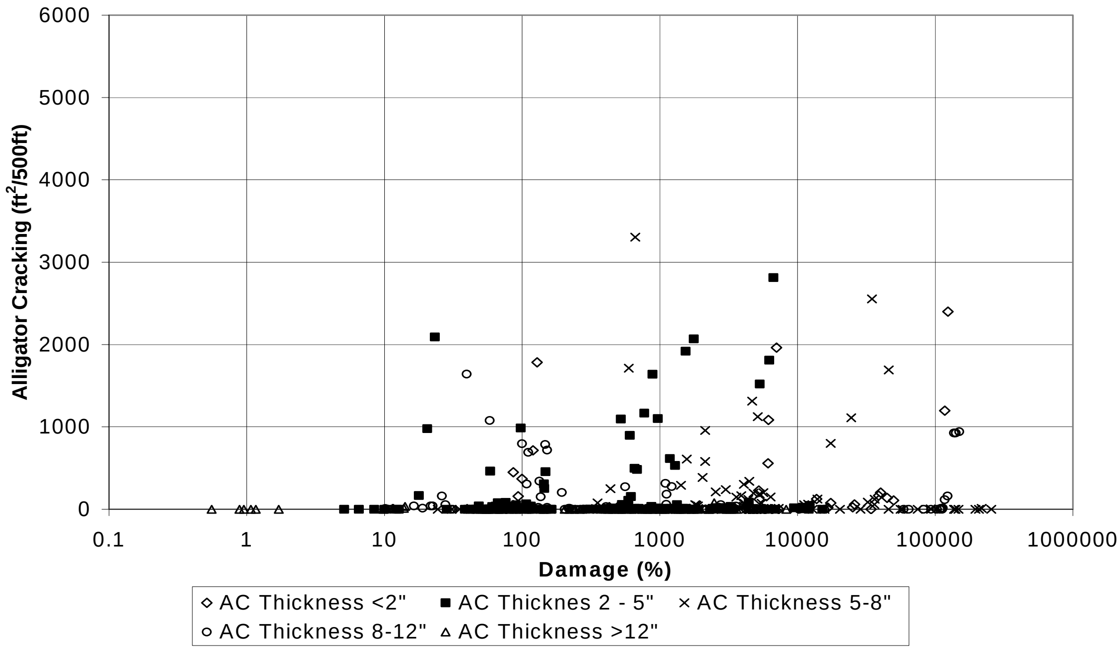

Figure B-1 Alligator Cracking vs. Predicted Bottom-Up Damage (AC 1,0.9,0.9)

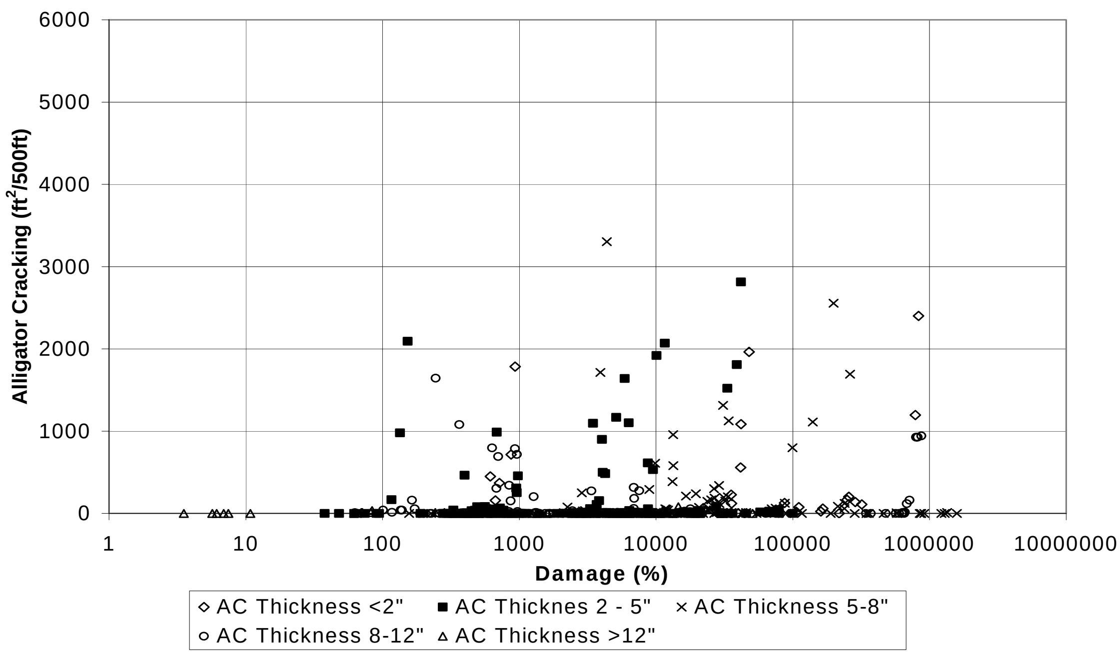

Figure B-2 Alligator Cracking vs. Predicted Bottom-Up Damage (AC 1,0.9,1.0)

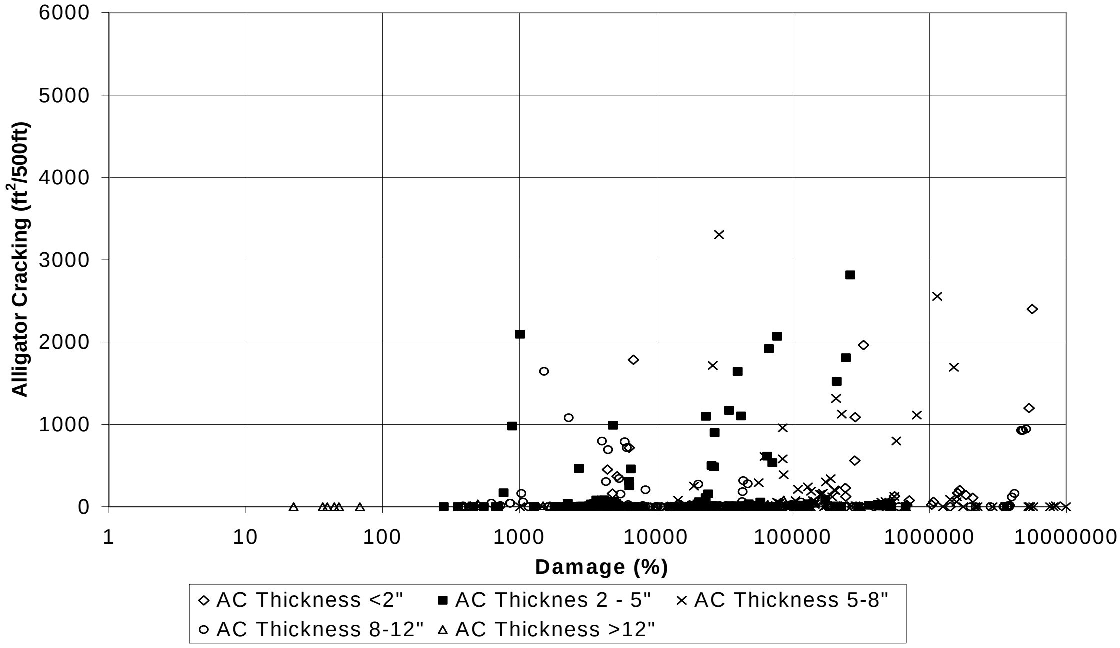

Figure B-3 Alligator Cracking vs. Predicted Bottom-Up Damage (AC 1,0.9,1.1)

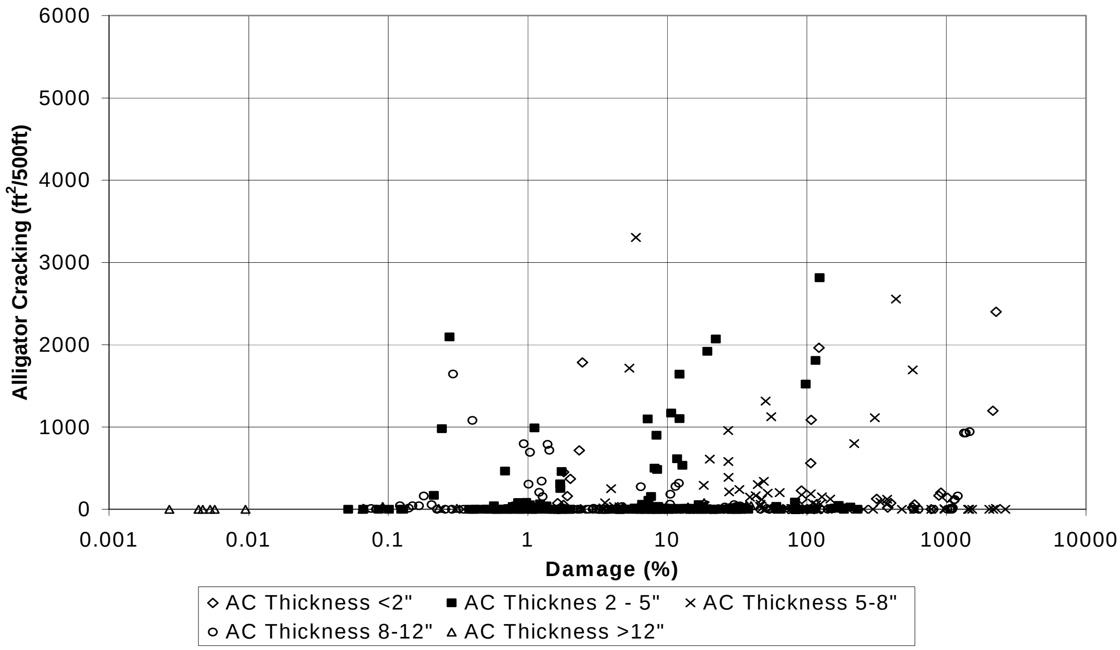

Figure B-4 Alligator Cracking vs. Predicted Bottom-Up Damage (AC 1,1.0,0.9)

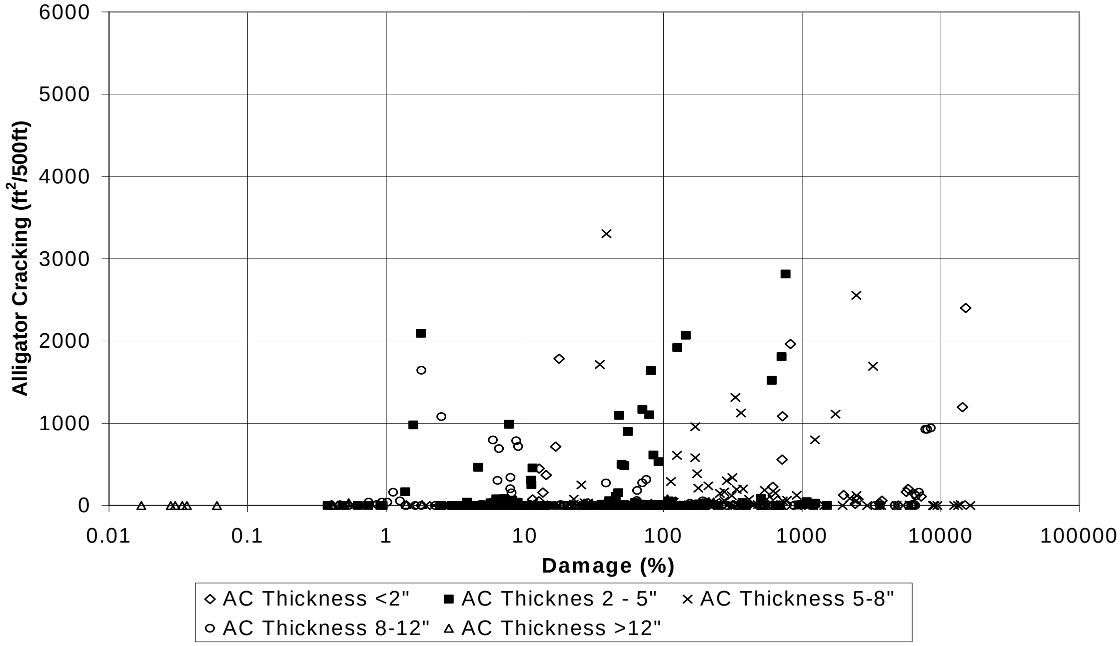

Figure B-5 Alligator Cracking vs. Predicted Bottom-Up Damage (AC 1,1.0,1.0)

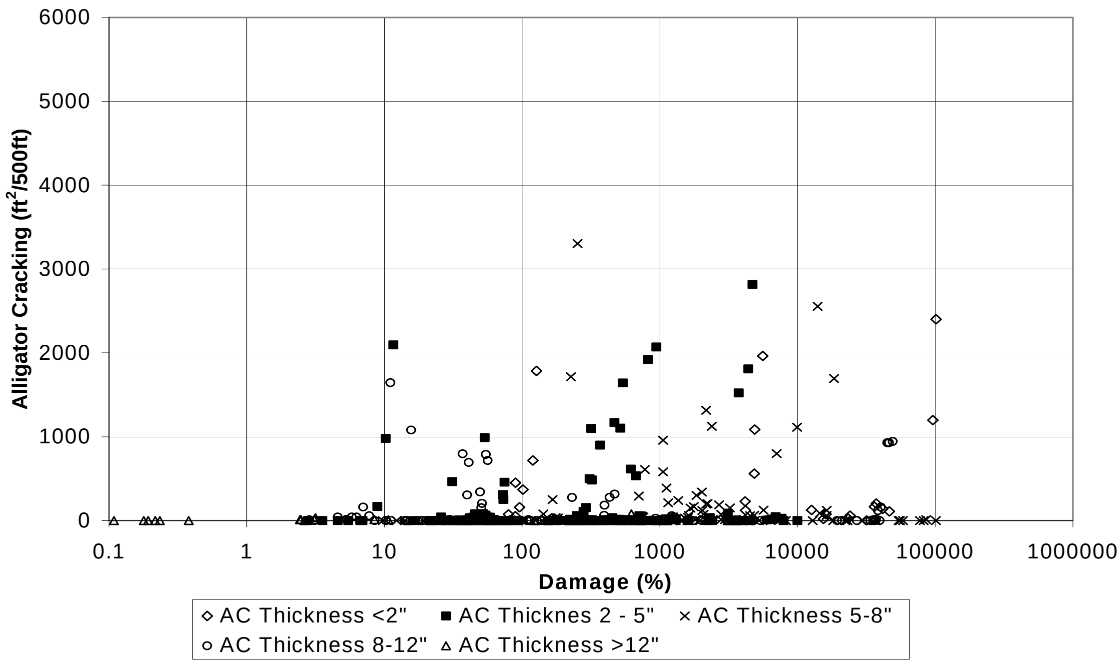

Figure B-6 Alligator Cracking vs. Predicted Bottom-Up Damage (AC 1,1.0,1.1)

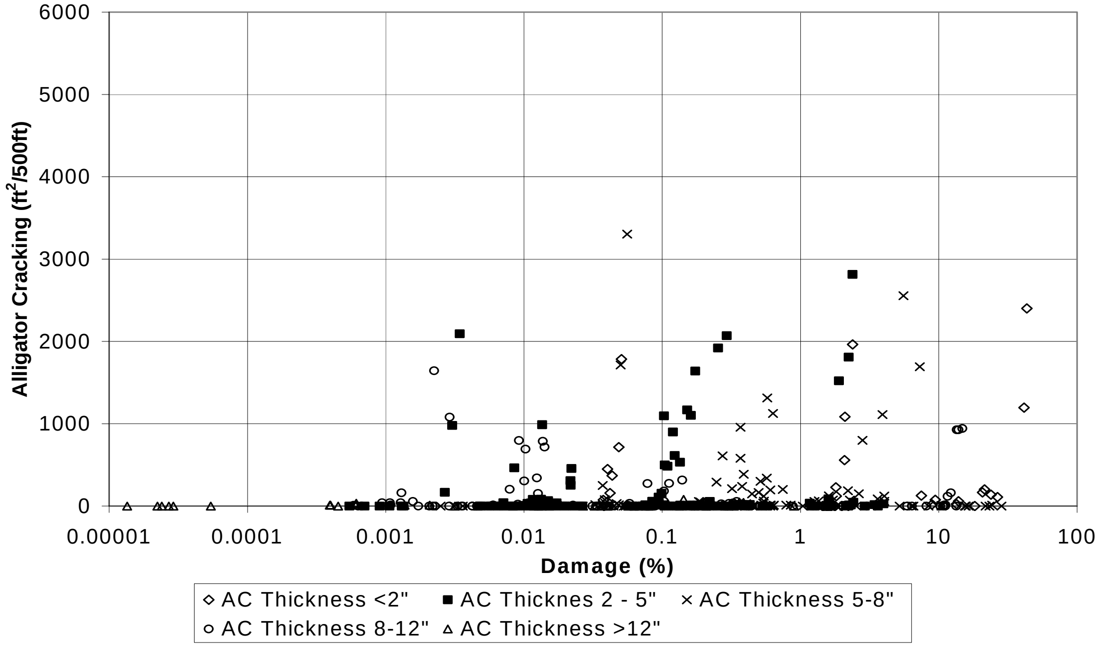

Figure B-7 Alligator Cracking vs. Predicted Bottom-Up Damage (AC 1,1.1,0.9)

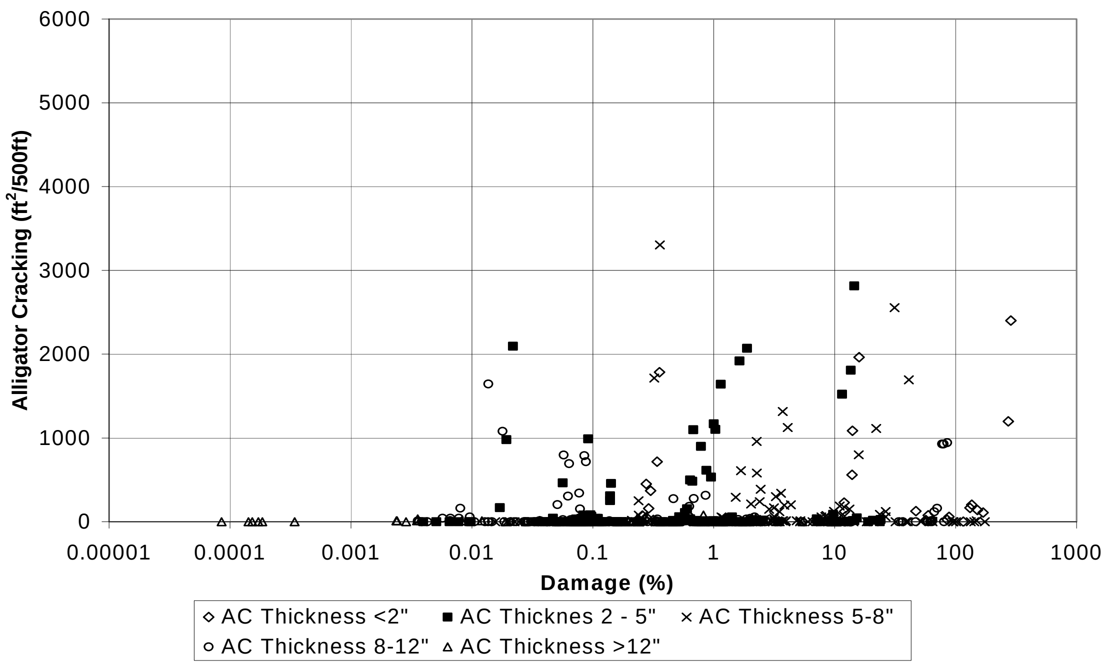

Figure B-8 Alligator Cracking vs. Predicted Bottom-Up Damage (AC 1,1.1,1.0)

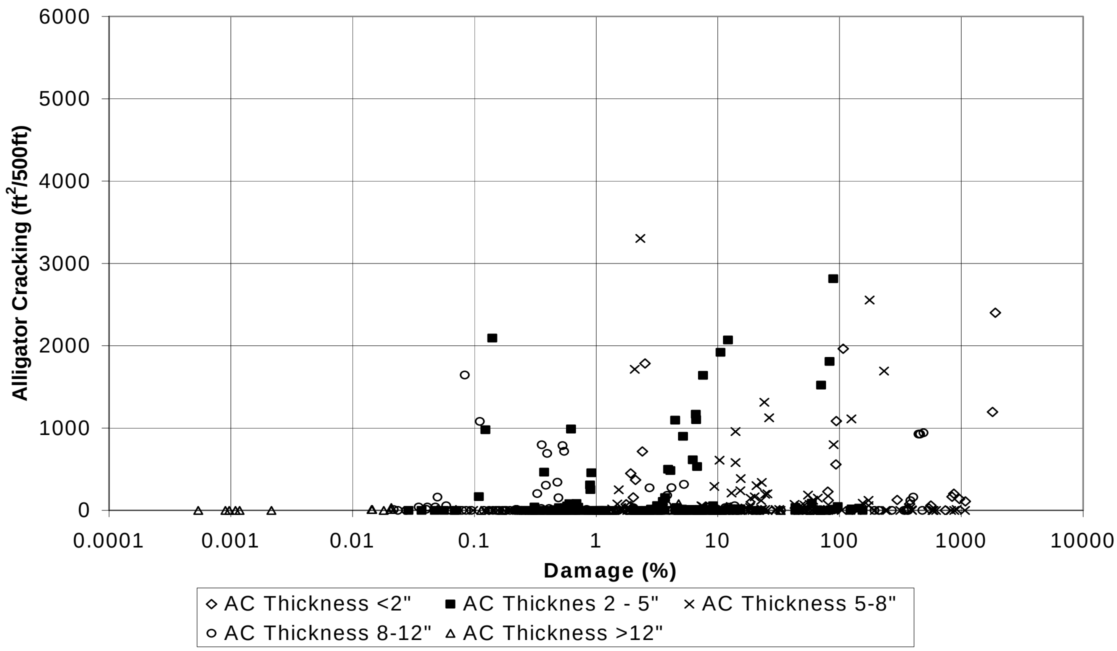

Figure B-9 Alligator Cracking vs. Predicted Bottom-Up Damage (AC 1,1.1,1.1)

ANNEX C

Bottom-Up Alligator Cracking Fatigue Cracking MS-1 MODEL CALIBRATION

Table C-1 Measured Alligator Fatigue Cracking and Predicted Bottom-up Damage Using MS1 Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.8,0.8	0.8,1.5	0.8,2.5	1.0,0.8	1.0,1.0
11001	3.2	Sep-91	132	8	0	0	8	579200	2E+09	3E+14	1607	15960
11001	3.2	Apr-92	139	13	0	0	13	608300	2.1E+09	3.3E+14	1677	16730
11001	3.2	Jul-92	142	13	0	0	13	624200	2.2E+09	3.3E+14	1726	17180
11001	3.2	Jan-93	148	45	0	0	45	653000	2.3E+09	3.5E+14	1805	17970
11019	6.7	May-89	32	0	0	0	0	41600	1.1E+08	1E+13	90.52	837.7
11019	6.7	Apr-90	43	0	0	0	0	55680	1.5E+08	1.4E+13	121.5	1121
11019	6.7	Jan-91	52	0	0	0	0	67900	1.7E+08	1.6E+13	149.7	1373
11019	6.7	Jun-91	57	800	0	0	800	74280	1.9E+08	1.8E+13	163.3	1501
11019	6.7	Mar-92		0	0	0		84480	2.2E+08	2.1E+13	185	1703
11019	6.7	Mar-93	78	1112	0	0	1112	99340	2.6E+08	2.6E+13	216.9	2000
11019	6.7	Jul-95	106	2554	0	0	2554	158900	4E+08	3.7E+13	370.7	3380
11019	6.7	Jan-98	136	0	1461	233	1693	202900	5.2E+08	4.9E+13	473.5	4323
14126	13.1	Jun-89	15	0	0	0	0	1038	3364000	3.5E+11	0.9166	9.229
14126	13.1	Mar-91	36	0	0	0	0	2622	8474000	8.7E+11	2.329	23.44
14126	13.1	Mar-93	60	0	0	0	0	4563	1.5E+07	1.5E+12	4.065	40.87
14126	13.1	Apr-94	73	0	0	0	0	5697	1.8E+07	1.9E+12	5.086	51.11
14126	13.1	Dec-95	93	6	22	0	28	7558	2.4E+07	2.5E+12	6.767	67.96
14126	13.1	Dec-97	117	81	0	0	81	9905	3.2E+07	3.2E+12	8.88	89.13
21001	3	May-90	83	0	0	0	0	8665	4.3E+07	9.8E+12	19.97	221.4
21001	3	Aug-91	98	0	0	0	0	10760	5.3E+07	1.2E+13	25.3	278.7
21001	3	Aug-93	122	0	0	0	0	13190	6.6E+07	1.5E+13	30.67	339.2
21001	3	Jun-95	144	0	0	0	0	15850	8E+07	1.8E+13	36.79	408.5
21001	3	Aug-97	170	0	0	0	0	18890	9.5E+07	2.2E+13	43.82	486
21001	3	Aug-98	182	0	3	0	3	20200	1E+08	2.3E+13	46.85	520.1
21002	3.3	May-90	68	0	0	0	0	2412	1.2E+07	2.7E+12	5.207	56.8
21002	3.3	Aug-91	83	0	0	0	0	2974	1.4E+07	3.2E+12	6.509	70.38
21002	3.3	Aug-93	107	0	0	0	0	3896	1.9E+07	4.3E+12	8.487	92.06
21002	3.3	Jun-95	129	0	0	0	0	4666	2.3E+07	5.3E+12	10.13	110
21002	3.3	Aug-97	155	0	0	0	0	5626	2.7E+07	6.3E+12	12.21	132.7
21002	3.3	May-98	164	0	0	0	0	5931	2.9E+07	6.9E+12	12.77	139.4
40113	4.5	Feb-95	19	0	0	0	0	46470	1.6E+08	2.3E+13	106.1	1039
40113	4.5	Mar-95	20	0	0	0	0	48540	1.7E+08	2.5E+13	110	1082
40113	4.5	Aug-95	25	0	0	0	0	66400	2.1E+08	2.9E+13	155.2	1503
40113	4.5	Nov-95	28	0	0	0	0	76030	2.5E+08	3.3E+13	177.3	1720
40113	4.5	Feb-96	31	0	0	0	0	80290	2.7E+08	3.9E+13	184	1798
40113	4.5	Apr-96	33	0	0	0	0	85620	2.9E+08	4.2E+13	195.3	1914
40113	4.5	Jul-96	36	0	0	0	0	98790	3.2E+08	4.4E+13	230.5	2232
40113	4.5	Aug-96	37	0	0	0	0	103700	3.3E+08	4.4E+13	243.7	2352
40113	4.5	Jan-98	54	0	0	0	0	154200	5.1E+08	7.4E+13	357	3467
40113	4.5	Apr-98	57	10	0	0	10	160300	5.4E+08	8.1E+13	367.7	3586
40113	4.5	Jun-98	59	10	0	0	10	168700	5.7E+08	8.4E+13	388	3781
40113	4.5	Oct-98	63	10	0	0	10	188500	6.2E+08	8.8E+13	438.1	4246
40114	6.8	Feb-95	19	0	0	0	0	25810	8E+07	1E+13	51.56	492.4
40114	6.8	Mar-95	20	0	0	0	0	26840	8.4E+07	1.1E+13	53.18	509.8
40114	6.8	Aug-95	25	0	0	0	0	37260	1.1E+08	1.3E+13	75.86	718.2

Table C-1 (Cont'd) Measured Alligator Fatigue Cracking and Predicted Bottom-up Damage Using MS1 Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.8,0.8	0.8,1.5	0.8,2.5	1.0,0.8	1.0,1.0
40114	6.8	Nov-95	28	0	0	0	0	42730	1.3E+08	1.4E+13	86.75	822.6
40114	6.8	Feb-96	31	0	0	0	0	44520	1.4E+08	1.6E+13	89.03	848.8
40114	6.8	Apr-96	33	0	0	0	0	47280	1.4E+08	1.8E+13	93.94	898.4
40114	6.8	Jul-96	36	0	0	0	0	55240	1.6E+08	1.9E+13	112.2	1062
40114	6.8	Aug-96	37	0	0	0	0	58330	1.7E+08	1.9E+13	119.4	1126
40114	6.8	Jan-98	54	0	0	0	0	85890	2.6E+08	3.1E+13	173.9	1647
40114	6.8	Apr-98	57	46	0	0	46	88640	2.7E+08	3.4E+13	177.9	1691
40114	6.8	Jun-98	59	52	0	0	52	93410	2.8E+08	3.5E+13	187.6	1783
40114	6.8	Oct-98	63	114	0	0	114	105000	3.1E+08	3.7E+13	213.1	2016
40115	15.1	Feb-95	19	0	0	0	0	472.7	1362000	1.5E+11	0.4743	4.459
40115	15.1	Mar-95	20	25	0	0	25	488.4	1426000	1.6E+11	0.4858	4.582
40115	15.1	Jan-98	54	0	0	0	0	1615	4485000	4.9E+11	1.651	15.4
40116	16.2	Feb-95	19	0	0	0	0	442.4	1286000	1.5E+11	0.3974	3.745
40116	16.2	Mar-95	20	0	0	0	0	457	1346000	1.5E+11	0.407	3.848
40116	16.2	Jan-98	54	0	0	0	0	1505	4209000	4.6E+11	1.379	12.88
40117	11.8	Feb-95	19	0	0	0	0	667.3	2179000	2.9E+11	0.717	6.99
40117	11.8	Mar-95	20	0	0	0	0	691.5	2287000	3.1E+11	0.7369	7.209
40117	11.8	Jan-98	54	0	0	0	0	2266	7123000	9.2E+11	2.485	24.01
40118	11.7	Feb-95	19	0	0	0	0	1506	4405000	5.1E+11	2.155	20.3
40118	11.7	Mar-95	20	0	0	0	0	1550	4592000	5.4E+11	2.198	20.77
40118	11.7	Jan-98	54	0	0	0	0	5136	1.5E+07	1.6E+12	7.427	69.6
41007	6.5	Sep-91	162	38	0	0	38	35430	9.6E+07	1E+13	68.3	629.2
41007	6.5	Feb-93	163	44	16	0	60	35630	9.7E+07	1.1E+13	68.59	632.3
41007	6.5	Sep-94	198	70	132	0	202	48060	1.3E+08	1.4E+13	92.18	851.6
41024	10.8	Nov-89	149	0	0	0	0	248500	5.9E+08	5.2E+13	452.3	4023
41024	10.8	Aug-90	158	0	0	0	0	272500	6.4E+08	5.7E+13	497.4	4418
41024	10.8	Oct-92	184	0	0	0	0	344400	8.1E+08	7.3E+13	627.8	5577
41024	10.8	Mar-95	213	0	0	0	0	422700	1E+09	9.4E+13	763.2	6801
41024	10.8	Jul-95	217	0	0	0	0	445100	1.1E+09	9.6E+13	806.8	7180
41024	10.8	Aug-95	218	12	0	0	12	452800	1.1E+09	9.7E+13	822.8	7316
41024	10.8	Nov-95	221	0	10	0	10	462900	1.1E+09	9.9E+13	839.7	7470
41024	10.8	Feb-96	224	0	0	0		464800	1.1E+09	1E+14	841.3	7489
41024	10.8	Apr-96	226	16	0	0	16	468000	1.1E+09	1E+14	845.2	7530
41024	10.8	Jun-96	228	118	0	0	118	477500	1.1E+09	1.1E+14	862.1	7682
41024	10.8	Aug-96	230	161	0	0	161	495700	1.2E+09	1.1E+14	901.3	8010
41024	10.8	Apr-98	250	0	398	529	927	560000	1.3E+09	1.2E+14	1011	9007
41024	10.8	Jun-98	252	0	397	530	927	571900	1.4E+09	1.3E+14	1033	9203
41024	10.8	Oct-98	256	0	414	529	943	598800	1.4E+09	1.3E+14	1083	9644
81029	4.2	Oct-91	233	27	15	0	42	9471	3.4E+07	5.9E+12	24.53	239.5
81029	4.2	Jul-94	266	0	0	0		10860	3.9E+07	6.9E+12	28.01	273.9
81029	4.2	Sep-95	280	464	0	0	464	11520	4.1E+07	7.3E+12	29.71	290.3
81053	4.6	Oct-89	60	0	0	0	0	4724	1.6E+07	2.3E+12	14.44	139.3
81053	4.6	Jul-90	69	0	0	0	0	5163	1.7E+07	2.7E+12	15.39	149.1
81053	4.6	Apr-93	102	3	0	0	3	8872	3E+07	4.8E+12	26.63	257.6
81053	4.6	Nov-93	109	0	0	0		11370	3.7E+07	5.5E+12	35.85	343.3
81053	4.6	Dec-93	110	23	0	0	23	11400	3.7E+07	5.5E+12	35.89	343.8
81053	4.6	Oct-94	120	0	0	0		14090	4.5E+07	6.6E+12	45.11	432

Table C-1 (Cont'd) Measured Alligator Fatigue Cracking and Predicted Bottom-up Damage Using MS1 Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.8,0.8	0.8,1.5	0.8,2.5	1.0,0.8	1.0,1.0
81053	4.6	Feb-95	124	40	0	0	40	14270	4.7E+07	7E+12	45.39	435.4
81053	4.6	May-95	127	40	0	0	40	14480	4.8E+07	7.2E+12	45.82	439.9
81053	4.6	May-96	139	0	0	0		15450	5.1E+07	7.9E+12	48.01	461.9
81053	4.6	Oct-96	144	310	0	0	310	16070	5.3E+07	8.1E+12	49.58	476.9
81053	4.6	Nov-96	145	253	0	0	253	16120	5.3E+07	8.1E+12	49.65	477.8
81053	4.6	Mar-97	149	457	0	0	457	16380	5.5E+07	8.7E+12	50.12	483.4
91803	7.2	Jul-89	49	0	0	0	0	2389	1E+07	2.2E+12	4.239	44.45
91803	7.2	Sep-90	63	0	0	0	0	3329	1.4E+07	3E+12	5.932	62.09
91803	7.2	Aug-91	74	0	0	0	0	4073	1.8E+07	3.8E+12	7.264	75.96
91803	7.2	Sep-92	87	8	0	0	8	5024	2.2E+07	4.7E+12	8.886	93.28
91803	7.2	May-94	107	211	0	0	211	6467	2.9E+07	6.6E+12	11.27	119.1
91803	7.2	May-95	119	240	0	0	240	7614	3.4E+07	7.8E+12	13.26	140.1
91803	7.2	Oct-96	136	84	82	0	166	9824	4.3E+07	9.5E+12	17.35	182.1
91803	7.2	May-97	143	301	0	0	301	10290	4.6E+07	1.1E+13	17.95	189.5
91803	7.2	Sep-97	147	15	325	0	340	11120	4.9E+07	1.1E+13	19.55	205.7
91803	7.2	Jun-98	156	195	0	0	195	11980	5.4E+07	1.2E+13	20.87	220.4
120103	12	Dec-96	14	0	0	0	0	146	394400	3.2E+10	0.1718	1.635
120104	18	Dec-96	14	0	0	0	0	30.49	80110	6.3E+09	0.02478	0.234
120105	7.9	Dec-96	14	0	0	0	0	614.1	1767000	1.6E+11	1.009	9.76
120106	15	Dec-96	14	0	0	0	0	54.58	145300	1.2E+10	0.05075	0.4808
123995	5	Apr-92	197	0	0	0		1949000	5.1E+09	4.2E+14	4385	40990
123995	5	Mar-94	220	86	0	0		2226000	5.8E+09	4.8E+14	5011	46830
123995	5	Jan-96	242	58	0	0		2486000	6.5E+09	5.4E+14	5597	52310
123995	5	Jan-96	243	122	0	0		2497000	6.5E+09	5.4E+14	5618	52520
123997	3.1	Aug-90	195	2000	0	0	2000	187100	5.5E+08	6.1E+13	546.3	5208
123997	3.1	Oct-91	209	0	3000	0	3000	208300	6.1E+08	6.8E+13	607.5	5797
123997	3.1	Mar-93	226	0	4680	0	4680	233200	7E+08	8E+13	676	6475
123997	3.1	Mar-94	238	0	5047	0	5047	254100	7.6E+08	8.6E+13	737.3	7060
124105	2.3	Apr-89	53	0	0	0	0	210200	6.8E+08	8.7E+13	707.7	6946
124105	2.3	Oct-91	83	0	0	0	0	331800	1.1E+09	1.3E+14	1123	10990
124105	2.3	Mar-93	100	0	0	0	0	397000	1.3E+09	1.7E+14	1333	13120
124106	8.2	Apr-89	21	0	0	0	0	36480	8.7E+07	6.2E+12	62.33	571
124106	8.2	Feb-91	43	0	0	0	0	72590	1.8E+08	1.3E+13	122.8	1130
124106	8.2	Jul-91	48	0	0	0	0	81270	2E+08	1.4E+13	137.6	1265
124106	8.2	Mar-94	80	0	0	0	0	132000	3.3E+08	2.5E+13	221.1	2043
124106	8.2	Jan-97	114	0	0	0	0	186000	4.6E+08	3.5E+13	310.6	2874
124107	2.7	Dec-89	75	0	0	0	0	21790	7.1E+07	8.5E+12	69.27	688.6
124107	2.7	Feb-91	89	0	0	0	0	26680	8.8E+07	1.1E+13	84.4	841.9
124107	2.7	Jul-91	94	0	0	0	0	28590	9.4E+07	1.1E+13	90.61	902.8
124107	2.7	Mar-93	114	732	355	9	1096	36220	1.2E+08	1.5E+13	114.1	1141
124107	2.7	Mar-94	126	656	243	0	899	41330	1.4E+08	1.8E+13	130.1	1302
124107	2.7	Jan-96	148	264	812	93	1168	51430	1.7E+08	2.2E+13	161.5	1620
124107	2.7	Mar-97	162	44	372	1224	1640	58280	2E+08	2.5E+13	182.7	1834
124108	9.9	Apr-89	35	0	0	0	0	3400	7231000	4.9E+11	5.259	45.81
124108	9.9	Jan-91	56	0	0	0	0	5477	1.2E+07	8.2E+11	8.49	73.73
124108	9.9	Oct-91	65	0	0	0	0	6532	1.4E+07	9.5E+11	10.16	88.1
124108	9.9	Mar-94	94	0	0	0	0	9477	2E+07	1.5E+12	14.6	127

Table C-1 (Cont'd) Measured Alligator Fatigue Cracking and Predicted Bottom-up Damage Using MS1 Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.8,0.8	0.8,1.5	0.8,2.5	1.0,0.8	1.0,1.0
124108	9.9	Aug-94	99	0	0	0	0	10210	2.2E+07	1.5E+12	15.77	137
124108	9.9	Jan-96	116	0	0	0	0	12000	2.6E+07	1.9E+12	18.43	160.6
124135	1.4	Dec-89	227	1112	86	0	1198	2242000	9E+09	1.5E+15	9282	96800
124135	1.4	Jan-91	240	2045	355	0	2400	2364000	9.5E+09	1.6E+15	9771	102000
131031	11.1	Apr-91	119	0	0	0	0	2633	7799000	9.6E+11	3.815	36.13
131031	11.1	Jul-92	134	0	0	0	0	3387	9872000	1.2E+12	4.94	46.68
131031	11.1	Jan-93	140	0	0	0	0	3646	1.1E+07	1.3E+12	5.32	50.24
131031	11.1	Apr-94	155	0	0	0	0	4345	1.3E+07	1.6E+12	6.312	59.69
131031	11.1	Oct-94	161	0	0	0	0	4840	1.4E+07	1.7E+12	7.044	66.6
131031	11.1	Aug-95	171	0	0	0	0	5448	1.6E+07	1.9E+12	7.954	75.09
131031	11.1	Jan-96	176	0	0	0	0	5701	1.7E+07	2E+12	8.285	78.34
131031	11.1	Apr-96	179	0	0	0	0	5784	1.7E+07	2.1E+12	8.365	79.22
134111	8.7	Mar-89	101	0	0	0	0	8295	2.2E+07	2.5E+12	20.21	185.3
134111	8.7	Mar-91	125	0	0	0	0	12460	3.4E+07	3.8E+12	30.31	278.1
134111	8.7	Feb-92	136	316	0	0	316	14530	3.9E+07	4.4E+12	35.31	324
134112	15.9	May-89	144	0	0	0	0	15190	3.4E+07	2.4E+12	21.92	193.4
134112	15.9	Feb-91	165	0	0	0	0	18840	4.2E+07	3E+12	27.2	239.9
134112	15.9	Apr-91	167	0	0	0	0	19110	4.2E+07	3.1E+12	27.52	243
134112	15.9	Feb-94	201	0	0	0	0	26380	5.8E+07	4.2E+12	38	335.4
134112	15.9	Oct-94	209	0	0	0	0	28560	6.3E+07	4.5E+12	41.24	363.8
134112	15.9	Jan-96	224	0	0	0	0	31670	7E+07	5.1E+12	45.63	402.7
134112	15.9	Feb-97	237	0	0	0	0	34900	7.7E+07	5.6E+12	50.24	443.5
134112	15.9	Apr-98	251	0	0	0	0	38620	8.6E+07	6.2E+12	55.53	490.4
134113	15.2	May-89	144	0	0	0	0	22370	5.4E+07	4.4E+12	32.42	294.1
134113	15.2	Feb-91	165	0	0	0	0	26890	6.6E+07	5.5E+12	38.98	353.4
134113	15.2	Apr-91	167	0	0	0	0	27210	6.7E+07	5.6E+12	39.36	357.2
134113	15.2	Feb-94	201	0	0	0	0	35950	8.8E+07	7.3E+12	52	471.8
134113	15.2	Oct-94	209	0	0	0	0	38540	9.4E+07	7.6E+12	55.85	506.4
134113	15.2	Jan-96	224	0	0	0	0	42140	1E+08	8.6E+12	60.96	553
134113	15.2	Feb-97	237	47	0	0	47	45870	1.1E+08	9.4E+12	66.3	601.6
134113	15.2	Apr-98	251	44	0	0	44	50120	1.2E+08	1E+13	72.36	657
161001	3.7	Jul-89	192	0	0	0	0	377700	1.6E+09	3E+14	1167	11890
161001	3.7	Aug-90	205	0	0	0	0	437100	1.8E+09	3.4E+14	1369	13910
161001	3.7	Jun-93	239	36	0	0	36	541400	2.2E+09	4.4E+14	1674	17070
161001	3.7	Aug-94	253	16	0	0	16	595500	2.4E+09	4.8E+14	1844	18780
161001	3.7	May-95	262	0	0	0		627500	2.6E+09	5.2E+14	1929	19720
161001	3.7	Jul-97	288	3	611	0	615	754000	3.1E+09	6.1E+14	2345	23880
161001	3.7	Sep-98	302	0	434	99	533	796400	3.3E+09	6.4E+14	2454	25030
161009	10.4	Sep-89	180	0	0	0	0	3109	8951000	1.2E+12	3.994	36.7
161009	10.4	Jul-90	190	0	0	0	0	3347	9725000	1.3E+12	4.283	39.44
161009	10.4	Jul-92	214	23	0	0	23	4060	1.2E+07	1.6E+12	5.193	47.8
161009	10.4	Oct-93	229	0	0	0		4640	1.3E+07	1.8E+12	5.96	54.75
161009	10.4	Jun-96	261	0	0	0		5746	1.7E+07	2.4E+12	7.309	67.47
161009	10.4	Jul-97	274	4	0	4	9	6362	1.9E+07	2.6E+12	8.131	74.87
161021	5.9	Sep-89	48	0	0	0	0	2625	9007000	1.5E+12	4.924	47.62
161021	5.9	Oct-90	61	0	0	0	0	3309	1.1E+07	1.9E+12	6.213	60.04
161021	5.9	Aug-91	71	0	0	0	0	3845	1.3E+07	2.2E+12	7.208	69.66

Table C-1 (Cont'd) Measured Alligator Fatigue Cracking and Predicted Bottom-up Damage Using MS1 Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.8,0.8	0.8,1.5	0.8,2.5	1.0,0.8	1.0,1.0
161021	5.9	Aug-93	95	0	0	0	0	5154	1.8E+07	3.1E+12	9.625	93.13
161021	5.9	Sep-95	120	0	0	0	0	6622	2.3E+07	3.9E+12	12.38	119.8
161021	5.9	Jun-96	129	0	0	0	0	7029	2.5E+07	4.3E+12	13.05	126.6
161021	5.9	Jul-97	142	0	0	0	0	7828	2.8E+07	4.8E+12	14.55	141.1
169034	9.2	Jul-89	10	0	0	0	0	159.7	618600	1.1E+11	0.1984	2.01
169034	9.2	Aug-90	23	0	0	0	0	421.6	1480000	2.4E+11	0.5622	5.509
169034	9.2	Jun-93	57	0	0	0	0	942.8	3496000	6.2E+11	1.22	12.1
169034	9.2	Aug-94	71	0	0	0	0	1216	4403000	7.6E+11	1.596	15.73
169034	9.2	May-95	80	0	0	0	0	1313	4870000	8.7E+11	1.701	16.86
169034	9.2	Jul-97	106	25	0	0	25	1777	6500000	1.2E+12	2.323	22.93
169034	9.2	Sep-98	120	0	0	25	25	2023	7375000	1.3E+12	2.647	26.12
201009	11.1	Aug-88	44	10	0	0	10	502.3	1350000	1.5E+11	0.6331	5.809
201009	11.1	May-89	53	0	0	0		572.3	1583000	1.8E+11	0.7104	6.556
201009	11.1	Dec-90	72	42	0	0	42	811	2203000	2.5E+11	1.017	9.343
201009	11.1	Oct-91	82	1	13	0	14	950.2	2550000	2.8E+11	1.199	10.98
201009	11.1	Apr-93	100	6	18	16	41	1110	3067000	3.6E+11	1.379	12.7
201009	11.1	Apr-95	124	2	54	0	56	1413	3878000	4.5E+11	1.765	16.21
201009	11.1	Apr-96	136	0	0	0		1554	4282000	5E+11	1.937	17.81
201009	11.1	Jan-99	168	0	1643	0		2005	5472000	6.3E+11	2.507	23.01
251003	6.6	Aug-89	180	0	0	0	0	29330	1.1E+08	1.8E+13	59.3	594.2
251003	6.6	Sep-90	193	0	0	0	0	31870	1.2E+08	2E+13	64.2	644.4
251003	6.6	Aug-91	204	28	0	0	28	34150	1.3E+08	2.1E+13	68.76	690.1
251003	6.6	Sep-92	217	56	93	0	149	37360	1.4E+08	2.3E+13	75.53	756.7
251003	6.6	Oct-95	254	45	75	0	121	45700	1.7E+08	2.8E+13	91.87	922.6
251003	6.6	Oct-96	266	1314	0	0	1314	48710	1.8E+08	3E+13	97.99	983.8
251003	6.6	Jun-98	286	1062	62	0	1125	53580	2E+08	3.4E+13	107.7	1081
251004	9.6	Aug-89	178	0	0	0	0	10400	3.9E+07	6.9E+12	17.96	181.1
251004	9.6	Sep-90	191	0	0	0	0	11610	4.4E+07	7.7E+12	20.06	202.3
251004	9.6	Aug-91	202	0	0	0	0	12630	4.8E+07	8.5E+12	21.8	219.9
251004	9.6	Sep-92	215	0	0	0	0	14140	5.4E+07	9.4E+12	24.46	246.5
251004	9.6	Oct-95	252	0	0	0	0	18430	7E+07	1.2E+13	31.73	320.3
251004	9.6	Jun-97	272	56	0	0	56	20870	8E+07	1.4E+13	35.79	361.6
251004	9.6	Jun-98	284	0	0	0		22670	8.7E+07	1.6E+13	38.89	392.9
261001	2.2	Jul-88	203	0	0	0	0	19320	8.5E+07	1.7E+13	53.97	572
261001	2.2	Sep-89	217	0	0	0	0	20680	9.1E+07	1.8E+13	57.82	612.1
261001	2.2	Jul-90	227	0	0	0	0	21540	9.5E+07	1.9E+13	60.14	637.4
261001	2.2	Jul-91	239	33	0	0	33	22650	1E+08	2E+13	63.25	670.2
261001	2.2	Sep-91	241	28	0	0	28	22850	1E+08	2E+13	63.87	676.3
261001	2.2	Sep-92	253	40	0	0	40	23960	1.1E+08	2.1E+13	66.89	708.7
261001	2.2	Jun-93	262	0	81	0	81	24870	1.1E+08	2.2E+13	69.35	735.9
261001	2.2	Jun-93	263	76	0	0	76	24980	1.1E+08	2.2E+13	69.7	739
261001	2.2	May-95	285	58	0	0	58	26980	1.2E+08	2.4E+13	75.19	797.9
261001	2.2	Jul-96	299	83	0	0	83	28310	1.2E+08	2.5E+13	78.97	837.2
261004	4.2	Sep-89	51	0	0	0	0	7972	3.2E+07	5.9E+12	18.76	192.7
261004	4.2	Jul-90	61	0	0	0	0	9566	3.9E+07	7.5E+12	22.39	230.9
271018	4.4	Apr-89	124	0	0	0	0	129900	4.6E+08	7.4E+13	314.8	3103
271018	4.4	Jun-89	126	0	0	0	0	134700	4.7E+08	7.5E+13	327.9	3226

Table C-1 (Cont'd) Measured Alligator Fatigue Cracking and Predicted Bottom-up Damage Using MS1 Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.8,0.8	0.8,1.5	0.8,2.5	1.0,0.8	1.0,1.0
271018	4.4	Oct-90	142	0	0	0	0	162000	5.6E+08	8.8E+13	395.5	3884
271018	4.4	Jun-93	174	0	0	0	0	211900	7.5E+08	1.2E+14	513.2	5060
271018	4.4	Jul-93	176	0	0	0	0	218000	7.6E+08	1.2E+14	530.9	5217
271018	4.4	Mar-94	183	0	0	0	0	224100	7.9E+08	1.3E+14	542.7	5345
271018	4.4	Aug-94	188	0	0	0	0	238700	8.4E+08	1.3E+14	581.4	5714
271087	15.7	Oct-91	154	0	0	0	0	379.8	1220000	1.6E+11	0.2847	2.763
271087	15.7	May-93	173	0	0	0	0	415.1	1345000	1.8E+11	0.3096	3.01
271087	15.7	Oct-94	190	0	3	0	3	462.6	1489000	2E+11	0.346	3.36
271087	15.7	Jun-96	210	13	0	0	13	506.5	1640000	2.2E+11	0.3778	3.672
291008	11.4	Feb-92	70	41	0	0	41	387.8	1102000	1.3E+11	0.4881	4.56
291008	11.4	Mar-93	83	140	22	0	161	460.8	1321000	1.6E+11	0.5759	5.391
291008	11.4							465.1	1338000	1.6E+11	0.5799	5.433
291008	11.4	Apr-96	120	0	0	0		704.9	2030000	2.5E+11	0.8789	8.23
291008	11.4	Feb-00	152	365	715	0		967.7	2765000	3.3E+11	1.209	11.31
307088	4.9	Sep-89	100	0	0	0	0	13260	5.2E+07	1E+13	32.17	321.6
307088	4.9	May-91	120	0	66	0	66	16060	6.4E+07	1.3E+13	38.67	388.1
308129	3.2	Oct-89	17	0	0	0	0	6017	2.6E+07	5.2E+12	14.94	156.3
308129	3.2	Jul-91	38	0	0	0	0	15580	7.2E+07	1.6E+13	39.33	420.1
308129	3.2	Jul-92	50	0	0	0	0	20320	9.6E+07	2.2E+13	50.62	542.9
308129	3.2	Aug-93	63	0	0	0	0	25680	1.2E+08	2.8E+13	63.54	681.1
308129	3.2	Dec-93	67	0	0	0	0	26990	1.3E+08	3E+13	66.39	712.9
308129	3.2	Mar-94	70	0	0	0	0	28390	1.4E+08	3.3E+13	69.33	749.5
308129	3.2	Oct-94	77	0	0	0	0	34280	1.6E+08	3.7E+13	86.52	926.7
308129	3.2	Feb-95	81	0	0	0	0	35770	1.7E+08	4.1E+13	89.36	962.7
308129	3.2	May-95	84	0	0	0	0	36890	1.8E+08	4.3E+13	91.7	989.8
308129	3.2	Jun-96	97	0	0	0	0	42830	2.1E+08	5E+13	105.8	1142
308129	3.2	Oct-96	101	0	0	0	0	45130	2.2E+08	5.1E+13	111.9	1204
308129	3.2	Jan-97	104	0	0	0	0	46050	2.2E+08	5.4E+13	113.5	1225
308129	3.2	Mar-97	106	0	0	0	0	46790	2.3E+08	5.5E+13	114.8	1242
308129	3.2	Aug-97	111	0	0	0	0	49810	2.4E+08	5.7E+13	122.9	1323
308129	3.2	Oct-97	113	0	0	0	0	50820	2.4E+08	5.8E+13	125.3	1349
321020	7	Jul-91	86	0	0	0	0	4976	1.7E+07	2.7E+12	9.157	89.42
321020	7	Aug-93	111	18	0	0	18	6869	2.4E+07	3.8E+12	12.65	123.4
321020	7	Sep-94	123	187	62	0	250	7837	2.7E+07	4.3E+12	14.41	140.6
321020	7	Apr-95	131	34	0	0	34	8257	2.9E+07	4.8E+12	15.02	147.2
321020	7	Jun-97	157	672	1043	0		10730	3.7E+07	6.2E+12	19.55	191.5
321020	7	Jun-98	169	3269	36	0		11820	4.1E+07	6.9E+12	21.48	210.6
341031	7.3	Apr-92	224	280	12	0	292	17460	5.3E+07	7.2E+12	41.28	388.7
341031	7.3	Feb-93	234	598	11	0	609	19250	5.8E+07	7.8E+12	45.62	429.3
341031	7.3	Oct-95	266	0	652	305	957	26060	7.8E+07	1E+13	61.8	581.1
341031	7.3	Nov-95	267	574	8	0	581	26130	7.9E+07	1E+13	61.89	582.2
341033	7.4	Apr-92	211	79	0	0	79	8149	2.6E+07	3.8E+12	13.98	134
341033	7.4	Feb-93	221	6	0	0	6	8628	2.8E+07	4E+12	14.82	142
341033	7.4	Nov-95	254	15	0	0	15	10140	3.3E+07	4.7E+12	17.42	166.8
341033	7.4	Jul-97	274	0	0	0		10950	3.6E+07	5.2E+12	18.71	179.6
341034	11.1	Oct-89	48	0	0	0	0	1324	4447000	6.3E+11	1.35	13.27
341034	11.1	Sep-90	59	0	0	0	0	1668	5576000	8E+11	1.712	16.77

Table C-1 (Cont'd) Measured Alligator Fatigue Cracking and Predicted Bottom-up Damage Using MS1 Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.8,0.8	0.8,1.5	0.8,2.5	1.0,0.8	1.0,1.0
341034	11.1	Apr-92	78	0	0	0	0	2124	7380000	1.1E+12	2.135	21.06
341034	11.1	Feb-93	88	0	0	0	0	2499	8578000	1.3E+12	2.529	24.88
341034	11.1	Nov-95	121	0	0	0	0	3793	1.3E+07	1.9E+12	3.859	37.89
341034	11.1	Jul-97	141	129	75	0	205	4550	1.6E+07	2.4E+12	4.609	45.33
350101	7.2	May-97	19	0	0	0	0	20630	6.3E+07	7.5E+12	47.7	454.1
350102	4.8	May-97	19	0	0	0	0	51290	1.8E+08	2.6E+13	134.7	1333
350103	12.5	May-97	19	0	0	0	0	10160	2.8E+07	2.8E+12	18.66	173.4
350104	19.2	May-97	19	0	0	0	0	1929	5097000	4.8E+11	2.421	22.27
350105	9.9	May-97	19	0	0	0	0	32310	8.2E+07	7.6E+12	70.29	634.8
350106	15.6	May-97	19	0	0	0	0	3376	9126000	9.1E+11	4.72	43.56
351005	8.9	Oct-89	73	0	0	0	0	1658	5689000	8.5E+11	2.571	25.33
351005	8.9	Mar-91	90	0	0	0	0	2058	7345000	1.2E+12	3.131	31.07
351005	8.9	Oct-92	109	0	0	0	0	2812	9915000	1.6E+12	4.295	42.57
351005	8.9	Feb-94	125	0	0	0	0	3422	1.2E+07	2E+12	5.206	51.65
351005	8.9	Mar-95	138	0	0	0	0	4118	1.5E+07	2.3E+12	6.309	62.35
351005	8.9	Apr-97	163	0	0	0	0	5442	2E+07	3.2E+12	8.23	81.82
351022	6.3	Oct-89	37	0	0	0	0	2653	9472000	1.5E+12	5.22	51.88
351022	6.3	Mar-91	54	0	0	0	0	4186	1.5E+07	2.6E+12	8.192	81.38
351022	6.3	Oct-92	73	0	0	0	0	6716	2.4E+07	4E+12	13.28	131.5
351022	6.3	Feb-94	89	0	0	0	0	8673	3.2E+07	5.5E+12	16.99	168.7
351022	6.3	Mar-95	102	0	0	0	0	10690	3.9E+07	6.8E+12	20.88	207.6
351022	6.3	Apr-97	127	0	0	0	0	15250	5.5E+07	9.6E+12	30.02	297.3
351112	6.3	Dec-89	67	0	0	0	0	27900	7.2E+07	7.5E+12	66.1	598.2
351112	6.3	Jan-91	80	0	0	0	0	32630	8.5E+07	9E+12	76.56	695.6
351112	6.3	Mar-91	82	0	0	0	0	33070	8.7E+07	9.3E+12	77.29	703.3
351112	6.3	Jan-93	104	0	0	0	0	41870	1.1E+08	1.2E+13	97.77	889.5
351112	6.3	Feb-94	117	0	0	0	0	47010	1.2E+08	1.3E+13	109.7	998
351112	6.3	Oct-94	125	0	0	0	0	51400	1.3E+08	1.4E+13	120.5	1094
351112	6.3	Mar-95	130	9	0	0	9	52270	1.4E+08	1.5E+13	121.9	1109
351112	6.3	Apr-95	131	0	0	0	0	52640	1.4E+08	1.5E+13	122.6	1116
351112	6.3	Jun-95	133	0	0	0	0	53820	1.4E+08	1.5E+13	125.5	1142
351112	6.3	Nov-96	150	0	0	0	0	61130	1.6E+08	1.7E+13	142.4	1296
351112	6.3	Apr-97	155	0	0	0	0	61960	1.6E+08	1.8E+13	143.6	1310
351112	6.3	Sep-97	160	0	0	0	0	65240	1.7E+08	1.9E+13	152	1383
371024	4.8	Nov-89	109	167	0	0	167	3635	1.2E+07	1.6E+12	8.802	84.43
371024	4.8	Mar-91	125	889	89	0		4225	1.4E+07	1.9E+12	10.12	97.52
371024	4.8	Apr-92	138	1442	308	342		4793	1.6E+07	2.2E+12	11.44	110.4
371802	4.5	Mar-91	66	36	0	0	36	118500	3.5E+08	4.4E+13	485.4	4596
371802	4.5	Oct-92	85	51	36	0	86	156400	4.6E+08	5.6E+13	646	6093
371802	4.5	Apr-94	103	1521	0	0	1521	185300	5.6E+08	7E+13	757.5	7181
371802	4.5	Jul-95	118	1739	70	0	1809	216000	6.4E+08	8E+13	888.9	8397
371802	4.5	Apr-96	127	2608	206	0	2814	230000	6.9E+08	8.8E+13	942	8919
371992	2.4	Mar-91	14	0	0	0	0	13640	5.2E+07	8.5E+12	37.76	388.2
371992	2.4	Oct-92	33	2	0	0	2	35710	1.3E+08	1.9E+13	102.5	1027
371992	2.4	Apr-94	51	0	0	0	0	57920	2.2E+08	3.5E+13	163.1	1653
371992	2.4	Feb-96	73	0	0	0	0	90340	3.4E+08	5.7E+13	253.5	2573
404087	10.1	Jan-90	43	0	0	0	0	3111	7294000	6.6E+11	7.66	67.85

Table C-1 (Cont'd) Measured Alligator Fatigue Cracking and Predicted Bottom-up Damage Using MS1 Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.8,0.8	0.8,1.5	0.8,2.5	1.0,0.8	1.0,1.0
404087	10.1	Oct-91	64	0	0	0	0	5015	1.2E+07	1.1E+12	12.27	108.9
404087	10.1	Nov-92	77	0	0	0	0	6140	1.5E+07	1.3E+12	14.89	132.4
404087	10.1	Feb-93	80	0	0	0	0	6183	1.5E+07	1.4E+12	14.93	132.9
404087	10.1	Nov-94	101	0	0	0	0	8491	2E+07	1.9E+12	20.36	181.7
404087	10.1	Feb-95	104	32	0	0	32	8533	2.1E+07	2E+12	20.4	182.2
404087	10.1	Aug-95	110					9689	2.3E+07	2.2E+12	23.41	208.3
404087	10.1	Jun-97	132	67	207	0	273	12340	3E+07	2.9E+12	29.58	263.7
404163	11.5	Jan-90	34	0	0	0	0	4917	1.2E+07	1.2E+12	7.846	71.04
404163	11.5	Mar-91	48	0	0	0	0	6546	1.7E+07	1.8E+12	10.36	93.98
404163	11.5	Oct-91	55	0	0	0	0	7802	2E+07	2E+12	12.35	112.1
404163	11.5	Nov-92	68	0	0	0	0	9524	2.4E+07	2.5E+12	15.15	137.1
404163	11.5	Mar-93	72	0	0	0	0	9634	2.5E+07	2.6E+12	15.23	138.1
404163	11.5	Nov-94	92	0	0	0	0	12510	3.2E+07	3.3E+12	19.74	179.1
404163	11.5	Apr-96	109	27	0	0	27	14030	3.7E+07	4E+12	21.93	199.5
404163	11.5	Aug-97	125					16780	4.3E+07	4.6E+12	26.56	240.4
404163	11.5	Jan-99	141	13	0	0	13	18640	4.8E+07	5.2E+12	29.37	266.2
404165	8.1	Jan-90	68	0	0	0	0	10330	2.9E+07	3.7E+12	16.16	150.3
404165	8.1	Mar-91	82	0	0	0	0	12300	3.6E+07	4.5E+12	19.07	178
404165	8.1	Oct-91	89	0	0	0	0	13910	4E+07	4.8E+12	21.7	202.1
404165	8.1	Nov-92	102	0	0	0	0	15670	4.5E+07	5.7E+12	24.27	226.7
404165	8.1	Mar-93	106	0	0	0	0	15840	4.6E+07	6E+12	24.41	228.4
404165	8.1	Oct-94	125	1	2	0	3	19770	5.7E+07	7.1E+12	30.86	287.1
404165	8.1	Nov-94	126	0	0	0		19830	5.7E+07	7.2E+12	30.91	287.7
404165	8.1	Apr-95	131	3	0	0	3	20170	5.9E+07	7.6E+12	31.25	291.5
404165	8.1	Jun-95	133	3	0	0	3	20630	6E+07	7.7E+12	31.94	298.2
404165	8.1	Apr-96	143	0	0	0		22160	6.5E+07	8.4E+12	34.25	319.9
404165	8.1	Nov-96	150	0	0	0		23820	6.9E+07	8.7E+12	36.95	344.6
404165	8.1	May-97	156	32	0	0	32	24280	7.1E+07	9.2E+12	37.46	350.1
404165	8.1	Sep-97	160	40	0	0	40	25480	7.4E+07	9.4E+12	39.45	368.3
421599	12.3	Aug-89	25	0	0	0	0	2527	7295000	8.6E+11	3.47	32.59
421599	12.3	Sep-90	38	0	0	0	0	3454	1E+07	1.3E+12	4.54	42.99
421599	12.3	Mar-93	68	0	0	0	0	5506	1.7E+07	2.4E+12	6.833	65.52
421599	12.3	Sep-94	86	0	0	0	0	7259	2.3E+07	3E+12	8.93	85.52
421599	12.3	Jun-95	95	0	0	0	0	7866	2.5E+07	3.4E+12	9.546	91.86
421599	12.3	Jul-96	108	0	0	0	0	9138	2.9E+07	4E+12	11.03	106.1
421599	12.3	Mar-98	128	9	0	0	9	11100	3.6E+07	5E+12	13.27	127.9
451011	3.2	Mar-92	69	0	0	0	0	127700	4.2E+08	5.9E+13	339.3	3320
451011	3.2	Oct-92	76	0	0	0	0	143000	4.6E+08	6.3E+13	382.6	3728
451011	3.2	Jun-93	84	1101	0	0	1101	155200	5.2E+08	7.2E+13	410.9	4029
451011	3.2	Jan-96	115	11	46	0	57	214600	7.1E+08	9.9E+13	569.8	5579
451011	3.2	Jun-97	132	1729	41	150	1919	244900	8.2E+08	1.2E+14	647.6	6356
451011	3.2	Feb-99	150	1203	612	254	2070	279400	9.3E+08	1.3E+14	738.8	7252
473104	1.3	Aug-89	39	0	74	0		1142	5145000	1E+12	4.449	48.04
473104	1.3	Nov-89	42	0	0	0		1203	5429000	1.1E+12	4.642	50.17
473104	1.3	May-91	60	52	0	0		1749	8427000	1.8E+12	6.481	71.49
473104	1.3	Aug-91	63	451	0	0		1788	8545000	1.8E+12	6.609	72.75
473104	1.3	Oct-92	77	140	19	0		2147	1E+07	2.2E+12	7.797	86.1

Table C-1 (Cont'd) Measured Alligator Fatigue Cracking and Predicted Bottom-up Damage Using MS1 Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.8,0.8	0.8,1.5	0.8,2.5	1.0,0.8	1.0,1.0
473104	1.3	Aug-93	87	370	0	0		2481	1.2E+07	2.6E+12	8.952	99.23
473104	1.3	Nov-95	114	124	300	292		3491	1.7E+07	3.9E+12	12.46	139.3
473104	1.3	Oct-96	125	159	1217	407		3967	2E+07	4.4E+12	14.16	158.4
480001	2.4	Apr-89	1	0	0	0	0	2980	8545000	8E+11	13.39	128.9
480001	2.4	Oct-90	19	0	0	0	0	59780	1.6E+08	1.5E+13	284.7	2619
480001	2.4	May-91	26	0	0	0	0	79240	2.2E+08	2.4E+13	364.3	3425
480001	2.4	Feb-93	47	0	0	0	0	153300	4.4E+08	5E+13	705.6	6619
480001	2.4	Apr-93	49	0	0	0	0	160200	4.6E+08	5.3E+13	733.5	6902
480001	2.4	Feb-95	71	0	0	0	0	250800	7.4E+08	8.7E+13	1141	10780
480001	2.4	Mar-95	72	0	0	0	0	254300	7.5E+08	8.9E+13	1154	10920
480001	2.4	May-97	98	0	18	0	18	386300	1.1E+09	1.4E+14	1749	16580
480001	2.4	Mar-98	108	0	27	0	27	440600	1.3E+09	1.6E+14	1989	18880
481060	7.5	Jun-90	52	0	0	0	0	28110	9.4E+07	1.2E+13	47.77	474.6
481060	7.5	Feb-91	60	0	0	0	0	32630	1.1E+08	1.4E+13	55.36	549.9
481060	7.5	Apr-91	62	0	0	0	0	33540	1.1E+08	1.5E+13	56.64	563.8
481060	7.5	Mar-92	73	0	0	0	0	40640	1.4E+08	1.8E+13	68.51	682.2
481060	7.5	Feb-93	84	8	0	0	8	48430	1.6E+08	2.2E+13	81.62	812.7
481060	7.5	Mar-93	85	0	0	0	0	48930	1.7E+08	2.2E+13	82.31	820.2
481060	7.5	Oct-94	104	0	0	0	0	63860	2.2E+08	2.9E+13	107.6	1071
481060	7.5	Feb-95	108	0	0	0	0	65130	2.2E+08	3.1E+13	109.1	1088
481060	7.5	Mar-95	109	0	0	0	0	65550	2.3E+08	3.1E+13	109.6	1094
481060	7.5	Mar-95	112	0	0	0	0	68520	2.4E+08	3.2E+13	114.6	1144
481060	7.5	Jun-95	134	0	0	0	0	86330	3E+08	4.1E+13	143.5	1436
481060	7.5	Apr-97	137	0	0	0	0	90360	3.1E+08	4.2E+13	150.7	1506
481060	7.5	Jul-97	139	12	0	0	12	93270	3.2E+08	4.3E+13	156.2	1558
481060	7.5	Sep-97	154	0	0	0	0	106600	3.7E+08	5E+13	177.6	1775
481077	5.1	Apr-89	88	0	0	0	0	14210	5.8E+07	1.2E+13	25.39	259.3
481077	5.1	Nov-91	119	0	0	0	0	20040	8.1E+07	1.7E+13	35.95	366.4
481077	5.1	Oct-92	130	0	0	0	0	22040	8.9E+07	1.9E+13	39.43	402.4
481077	5.1	May-93	137	0	0	0	0	22850	9.4E+07	2E+13	40.62	415.8
481077	5.1	Oct-94	154	10	0	0	10	26560	1.1E+08	2.3E+13	47.5	484.8
481077	5.1	Mar-95	159	0	0	0	0	27050	1.1E+08	2.4E+13	48.1	492.1
481077	5.1	Apr-95	160	0	0	0	0	27230	1.1E+08	2.4E+13	48.38	495.2
481077	5.1	Jun-95	162	0	0	0	0	27780	1.1E+08	2.5E+13	49.42	505.6
481077	5.1	Aug-95	164	0	0	0	0	28480	1.2E+08	2.5E+13	50.9	519.6
481077	5.1	Jun-96	174	0	0	0	0	30130	1.2E+08	2.7E+13	53.66	548.6
481077	5.1	May-97	185	13	0	0	13	32140	1.3E+08	2.9E+13	57.08	584.2
481077	5.1	Jul-97	187	56	0	0	56	32790	1.3E+08	2.9E+13	58.37	596.8
481077	5.1	Sep-97	189	50	0	0	50	33420	1.4E+08	2.9E+13	59.61	609
481077	5.1	Mar-98	195	41	0	0	41	34010	1.4E+08	3.1E+13	60.34	617.8
481109	6.5	Jan-90	68	0	0	0	0	16250	3.2E+07	2E+12	54.76	463.3
481109	6.5	Sep-90	76	0	0	0	0	18850	3.7E+07	2.3E+12	63.73	538.6
481109	6.5	May-91	84	0	0	0	0	20270	4E+07	2.6E+12	67.59	574.2
481109	6.5	Feb-93	105	73	0	0	73	26310	5.2E+07	3.4E+12	87.69	744.4
481109	6.5	Jul-93	110	0	0	0		28130	5.6E+07	3.6E+12	93.81	796.4
481109	6.5	Feb-95	129	0	0	0		33480	6.7E+07	4.5E+12	110.9	943.4
481109	6.5	May-95	132	74	0	0	74	34310	6.9E+07	4.6E+12	113.4	965.5

Table C-1 (Cont'd) Measured Alligator Fatigue Cracking and Predicted Bottom-up Damage Using MS1 Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.8,0.8	0.8,1.5	0.8,2.5	1.0,0.8	1.0,1.0
481109	6.5	Aug-96	147	150	0	0	150	40200	8E+07	5.3E+12	133.3	1133
481130	2.7	Apr-89	200	0	0	0	0	326900	9.1E+08	1E+14	1296	12010
481130	2.7	Oct-90	218	0	0	0	0	366900	1E+09	1.1E+14	1461	13500
481130	2.7	Mar-91	223	490	44	0	534	374800	1E+09	1.2E+14	1486	13770
481130	2.7	Mar-92	235	830	26	0	856	400400	1.1E+09	1.3E+14	1586	14700
481169	1.1	Feb-90	211	0	0	0	0	281700	1.2E+09	2.5E+14	942.9	10090
481169	1.1	Mar-90	212	0	0	0	0	283100	1.3E+09	2.5E+14	947.3	10140
481169	1.1	Sep-90	218	0	0	0	0	292400	1.3E+09	2.6E+14	980.8	10480
481169	1.1	Jan-91	222	0	0	0	0	298200	1.3E+09	2.7E+14	998.3	10680
481169	1.1	Mar-91	224	0	0	0	0	301100	1.3E+09	2.7E+14	1007	10780
481169	1.1	Jun-91	227	0	0	0	0	305700	1.4E+09	2.7E+14	1023	10950
481169	1.1	Jan-92	234	0	0	0	0	316200	1.4E+09	2.8E+14	1058	11330
481169	1.1	Feb-93	247	0	0	0	0	336000	1.5E+09	3E+14	1124	12040
481169	1.1	Aug-93	253	0	0	0	0	345500	1.5E+09	3.1E+14	1158	12380
481169	1.1	Mar-95	272	0	0	0	0	375200	1.7E+09	3.4E+14	1254	13440
481169	1.1	Jul-95	276	0	0	0	0	381700	1.7E+09	3.4E+14	1278	13680
481169	1.1	Jul-97	300	0	0	0	0	419900	1.9E+09	3.8E+14	1405	15040
481174	4.7	Oct-90	186	0	0	0	0	168300	4E+08	3.6E+13	419.7	3758
481174	4.7	Feb-91	190	0	0	0	0	171800	4.1E+08	3.7E+13	426.9	3830
481174	4.7	Apr-91	192	0	16	0	16	174000	4.2E+08	3.8E+13	432	3879
481174	4.7	Mar-92	203	0	0	0		186200	4.5E+08	4E+13	462.3	4151
481174	4.7	Feb-93	214	22	0	0	22	197800	4.8E+08	4.3E+13	491	4409
481174	4.7	Mar-93	215	58	0	0	58	198700	4.8E+08	4.4E+13	492.7	4426
481174	4.7	Feb-95	238	28	0	0	28	223500	5.4E+08	4.9E+13	554.3	4979
481174	4.7	Mar-95	239	109	0	0	109	224500	5.5E+08	4.9E+13	556.2	4999
481174	4.7	Jan-96	249	154	0	0	154	235900	5.7E+08	5.2E+13	585	5255
481174	4.7	Apr-97	264	492	6	0	498	252300	6.1E+08	5.5E+13	625.1	5620
481174	4.7	Mar-98	275	422	61	0	483	263600	6.4E+08	5.8E+13	652.6	5869
481178	8.5	Apr-89	10	0	0	0	0	221.7	532700	4.4E+10	0.4335	3.881
481178	8.5	Feb-91	32	0	0	0	0	809	1853000	1.5E+11	1.613	14.3
481178	8.5	May-91	33	0	0	0	0	829.1	1913000	1.5E+11	1.646	14.62
481178	8.5	Feb-93	56	0	0	0	0	1473	3450000	2.9E+11	2.912	25.89
481178	8.5	Jul-93	61	0	0	0	0	1662	3851000	3.2E+11	3.298	29.27
481178	8.5	Feb-95	80	9	0	0	9	2302	5407000	4.6E+11	4.535	40.39
481178	8.5	Mar-95	81	9	0	0	9	2329	5490000	4.7E+11	4.578	40.81
481183	5.7	Sep-90	188	0	0	0	0	57400	1.4E+08	1.5E+13	205.4	1826
481183	5.7	Mar-91	194	0	79	0	79	58950	1.5E+08	1.7E+13	208.9	1863
481183	5.7	Oct-91	201	0	0	0		67350	1.7E+08	1.8E+13	241.7	2144
481183	5.7	Nov-91	202	0	0	0		67640	1.7E+08	1.8E+13	242.3	2151
481183	5.7	Jan-93	216	24	0	0	24	77930	2E+08	2.2E+13	277.1	2468
481183	5.7	Jul-93	222	9	0	40	48	84520	2.1E+08	2.3E+13	300.6	2677
481183	5.7	Apr-94	231	9	9	60	78	91360	2.3E+08	2.6E+13	323.7	2886
483749	1.8	Oct-90	116	0	0	0	0	958100	3.1E+09	4E+14	4290	41620
483749	1.8	Apr-91	122	0	0	0	0	999400	3.2E+09	4.4E+14	4448	43310
483749	1.8	Aug-91	126	0	0	0	0	1034000	3.3E+09	4.4E+14	4615	44860
483749	1.8	Mar-92	133	0	0	0	0	1086000	3.5E+09	4.8E+14	4822	47000
483749	1.8	Feb-93	144	55	132	41	228	1172000	3.8E+09	5.2E+14	5198	50700

Table C-1 (Cont'd) Measured Alligator Fatigue Cracking and Predicted Bottom-up Damage Using MS1 Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.8,0.8	0.8,1.5	0.8,2.5	1.0,0.8	1.0,1.0
483749	1.8	Mar-93	145	47	75	0	123	1180000	3.9E+09	5.2E+14	5228	51020
483749	1.8	Feb-95	168	210	172	177	559	1357000	4.5E+09	6.1E+14	5994	58590
483749	1.8	Mar-95	169	41	1045	0	1086	1364000	4.5E+09	6.2E+14	6020	58870
483749	1.8	Mar-97	193	115	343	1504	1962	1551000	5.1E+09	7.1E+14	6822	66830
489005	1.2	Oct-90	50	126	0	0	126	367600	1.3E+09	2E+14	2101	21180
489005	1.2	Mar-91	55	19	0	0	19	404100	1.5E+09	2.4E+14	2295	23260
489005	1.2	Aug-91	60	75	0	0	75	440600	1.6E+09	2.6E+14	2500	25360
489005	1.2	Feb-93	78	24	0	0	24	572400	2.1E+09	3.4E+14	3240	32920
489005	1.2	Apr-93	80	58	0	0	58	587000	2.2E+09	3.5E+14	3313	33740
489005	1.2	Feb-95	102	0	0	0		744500	2.8E+09	4.6E+14	4182	42710
489005	1.2	Feb-96	114	165	0	0	165	834700	3.2E+09	5.2E+14	4686	47910
489005	1.2	Jul-96	119	202	0	0	202	873300	3.3E+09	5.5E+14	4895	50140
489005	1.2	Jul-97	131	140	0	0	140	961900	3.7E+09	6.1E+14	5387	55220
489005	1.2	Jul-98	143	110	0	0	110	1050000	4E+09	6.6E+14	5879	60280
501002	8.5	Aug-89	58	0	0	0		335.9	1333000	2.6E+11	0.4783	4.882
501002	8.5	Aug-90	70	0	0	0		411.5	1628000	3.1E+11	0.588	5.991
501002	8.5	May-94	115	795	0	0		676	2747000	5.4E+11	0.9504	9.747
501002	8.5	Aug-94	118	306	0	0		714.8	2857000	5.5E+11	1.014	10.36
501002	8.5	Apr-95	126	692	0	0		744.6	3032000	6E+11	1.046	10.72
501002	8.5	Oct-96	144	41	301	0		889.5	3568000	6.9E+11	1.258	12.87
501002	8.5	May-97	151	121	31	0		916.3	3727000	7.4E+11	1.287	13.2
501002	8.5	Oct-97	156	667	121	0		976.5	3915000	7.6E+11	1.382	14.13
501002	8.5	Jun-98	164	85	632	0		1022	4133000	8.2E+11	1.44	14.75
501004	8	Apr-93	102	46	0	0	46	638.5	2787000	6.5E+11	0.8861	9.18
501004	8	Oct-95	132	34	0	0	34	1022	4367000	9.9E+11	1.422	14.69
501004	8	Nov-97	157	391	674	0		1388	5910000	1.3E+12	1.934	19.95
511002	5.7	Apr-89	115	127	229	30	386	86270	3E+08	4.8E+13	231.8	2285
511023	10.1	Oct-89	107	0	0	0	0	8578	2.4E+07	2.8E+12	14.46	135.7
511023	10.1	Mar-91	124	0	0	0	0	9801	2.8E+07	3.4E+12	16.44	154.5
511023	10.1	May-92	138	0	0	0	0	11030	3.2E+07	3.9E+12	18.41	173.3
511023	10.1	Oct-92	143	13	0	0	13	11940	3.4E+07	4E+12	20.13	188.9
511023	10.1	Dec-93	157	11	0	0	11	13240	3.8E+07	4.5E+12	22.25	208.9
511023	10.1	Sep-95	178	61	0	0	61	15670	4.5E+07	5.3E+12	26.4	247.7
511023	10.1	Feb-96	183	182	0	0	182	15850	4.6E+07	5.5E+12	26.58	249.7
511023	10.1	Mar-97	196	276	0	0	276	17080	5E+07	6E+12	28.54	268.5
512021	7.5	Oct-89	54	0	0	0	0	9108	2.6E+07	3E+12	18.34	172.2
512021	7.5	Mar-91	71	31	0	0	31	11750	3.5E+07	4.2E+12	23.4	220.4
512021	7.5	Oct-92	90	0	0	0		16080	4.7E+07	5.5E+12	32.28	303.3
531008	3.4	Jul-91	153	11	17	5	33	28420	1.2E+08	2.5E+13	65.09	678
531008	3.4	Jun-93	176	25	24	6	55	33110	1.4E+08	2.9E+13	75.48	788.5
531008	3.4	Jun-94	188	135	439	414	988	35770	1.6E+08	3.2E+13	81.57	851.9
561007	2.8	Jul-90	121	0	0	0	0	9768	4.3E+07	9E+12	24.1	252.2
561007	2.8	May-91	131	0	0	0	0	10530	4.7E+07	9.8E+12	25.86	271.3
561007	2.8	Aug-91	134	0	0	0	0	10830	4.7E+07	9.9E+12	26.79	279.8
561007	2.8	Aug-93	158	0	0	0	0	12760	5.6E+07	1.2E+13	31.56	329.6
561007	2.8	Oct-93	160	0	0	0	0	12910	5.6E+07	1.2E+13	31.91	333.3
561007	2.8	Dec-93	162	5	0	0	5	13010	5.7E+07	1.2E+13	32.1	335.6

Table C-1 (Cont'd) Measured Alligator Fatigue Cracking and Predicted Bottom-up Damage Using MS1 Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.8,0.8	0.8,1.5	0.8,2.5	1.0,0.8	1.0,1.0
561007	2.8	Mar-94	165	8	0	0	8	13210	5.8E+07	1.2E+13	32.48	340.3
561007	2.8	Apr-94	166	0	0	0		13300	5.9E+07	1.2E+13	32.7	342.8
561007	2.8	Aug-94	170	6	0	0	6	13690	6E+07	1.3E+13	33.77	353.2
561007	2.8	Feb-95	176	0	0	0		14110	6.2E+07	1.3E+13	34.67	363.5
561007	2.8	May-95	179	0	0	0		14360	6.4E+07	1.3E+13	35.28	370.1
561007	2.8	Sep-95	183	0	0	0		14740	6.5E+07	1.4E+13	36.33	380.2
561007	2.8	Jun-96	192	12	0	0	12	15400	6.8E+07	1.4E+13	37.82	396.8
561007	2.8	Oct-96	196	0	0	0		15770	6.9E+07	1.5E+13	38.85	406.6
561007	2.8	Nov-96	197	0	0	0		15830	7E+07	1.5E+13	38.97	408
561007	2.8	Mar-97	201	0	0	0		16110	7.1E+07	1.5E+13	39.55	415
561007	2.8	Aug-97	206	0	0	0		16590	7.3E+07	1.5E+13	40.93	428
561007	2.8	Sep-97	207	0	0	0		16680	7.3E+07	1.5E+13	41.18	430.4

Table C-2 Measured Alligator Fatigue Cracking and Predicted Bottom-up Damage Using MS1 Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	1.0,1.5	1.0,2.5	1.2,0.8	1.2,1.5	1.2,2.5
11001	3.2	Sep-91	132	8	0	0	8	5232000	7.1E+11	4.775	16779.4	1.821E+09
11001	3.2	Apr-92	139	13	0	0	13	5553000	7.8E+11	4.953	17662.7	1.97E+09
11001	3.2	Jul-92	142	13	0	0	13	5668000	7.8E+11	5.116	18091.5	1.995E+09
11001	3.2	Jan-93	148	45	0	0	45	5936000	8.2E+11	5.345	18936.3	2.092E+09
11019	6.7	May-89	32	0	0	0	0	225400	1.9E+10	0.21	498.252	38530000
11019	6.7	Apr-90	43	0	0	0	0	300200	2.5E+10	0.2828	665.003	51070000
11019	6.7	Jan-91	52	0	0	0	0	362500	3E+10	0.3519	810.503	60820000
11019	6.7	Jun-91	57	800	0	0	800	397500	3.3E+10	0.3829	886.753	66890000
11019	6.7	Mar-92		0	0	0		453300	3.8E+10	0.4325	1006.25	76940000
11019	6.7	Mar-93	78	1112	0	0	1112	535900	4.6E+10	0.5059	1185	92180000
11019	6.7	Jul-95	106	2554	0	0	2554	877900	7.1E+10	0.931	2086.26	150600000
11019	6.7	Jan-98	136	0	1461	233	1693	1127000	9.3E+10	1.192	2677.51	195300000
14126	13.1	Jun-89	15	0	0	0	0	2969	3.1E+08	0.00086	13.6275	289400
14126	13.1	Mar-91	36	0	0	0	0	7527	7.8E+08	0.00221	33.65	736000
14126	13.1	Mar-93	60	0	0	0	0	13100	1.3E+09	0.00387	55.4	1279000
14126	13.1	Apr-94	73	0	0	0	0	16360	1.7E+09	0.00485	68.925	1597000
14126	13.1	Dec-95	93	6	22	0	28	21720	2.2E+09	0.00647	92.3	2121000
14126	13.1	Dec-97	117	81	0	0	81	28450	2.9E+09	0.0085	117.425	2775000
21001	3	May-90	83	0	0	0	0	94440	2E+10	0.05063	194.19	44620000
21001	3	Aug-91	98	0	0	0	0	117000	2.4E+10	0.06556	234.287	54580000
21001	3	Aug-93	122	0	0	0	0	143700	3E+10	0.07859	292.218	67690000
21001	3	Jun-95	144	0	0	0	0	174800	3.7E+10	0.09412	343.679	83700000
21001	3	Aug-97	170	0	0	0	0	207500	4.4E+10	0.1121	412.858	98770000
21001	3	Aug-98	182	0	3	0	3	222400	4.7E+10	0.1198	440.425	106400000
21002	3.3	May-90	68	0	0	0	0	23600	5E+09	0.01249	50.4254	9993000
21002	3.3	Aug-91	83	0	0	0	0	28680	5.9E+09	0.01585	62.1408	11880000
21002	3.3	Aug-93	107	0	0	0	0	37850	7.9E+09	0.02057	81.3252	15910000
21002	3.3	Jun-95	129	0	0	0	0	45460	9.6E+09	0.02452	97.4765	19240000
21002	3.3	Aug-97	155	0	0	0	0	54800	1.2E+10	0.02949	117.154	23150000
21002	3.3	May-98	164	0	0	0	0	58180	1.3E+10	0.03063	123.599	24860000
40113	4.5	Feb-95	19	0	0	0	0	329200	4.2E+10	0.2622	577.508	83590000
40113	4.5	Mar-95	20	0	0	0	0	345800	4.5E+10	0.2701	603.219	88620000
40113	4.5	Aug-95	25	0	0	0	0	460500	5.5E+10	0.3903	825.551	111900000
40113	4.5	Nov-95	28	0	0	0	0	527500	6.2E+10	0.4441	945.287	127600000
40113	4.5	Feb-96	31	0	0	0	0	564100	7.1E+10	0.4553	994.19	140900000
40113	4.5	Apr-96	33	0	0	0	0	603900	7.6E+10	0.4805	1059.73	151600000
40113	4.5	Jul-96	36	0	0	0	0	683800	8.1E+10	0.5782	1222.07	165700000
40113	4.5	Aug-96	37	0	0	0	0	713200	8.3E+10	0.6155	1282.57	170800000
40113	4.5	Jan-98	54	0	0	0	0	1073000	1.3E+11	0.8917	1900.15	265800000
40113	4.5	Apr-98	57	10	0	0	10	1124000	1.4E+11	0.9121	1972.75	283100000
40113	4.5	Jun-98	59	10	0	0	10	1181000	1.5E+11	0.9629	2077.36	295600000
40113	4.5	Oct-98	63	10	0	0	10	1307000	1.6E+11	1.097	2321.37	320600000
40114	6.8	Feb-95	19	0	0	0	0	145100	1.6E+10	0.1118	291.501	27360000
40114	6.8	Mar-95	20	0	0	0	0	151600	1.7E+10	0.1145	302.251	28870000
40114	6.8	Aug-95	25	0	0	0	0	206000	2.1E+10	0.1665	423.001	37380000
40114	6.8	Nov-95	28	0	0	0	0	236200	2.4E+10	0.1894	484.501	42730000

Table C-2 (Cont'd) Measured Alligator Fatigue Cracking and Predicted Bottom-up Damage Using MS1 Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	1.0,1.5	1.0,2.5	1.2,0.8	1.2,1.5	1.2,2.5
40114	6.8	Feb-96	31	0	0	0	0	248000	2.6E+10	0.1925	500.001	45930000
40114	6.8	Apr-96	33	0	0	0	0	264500	2.8E+10	0.2018	530.001	49310000
40114	6.8	Jul-96	36	0	0	0	0	304100	3E+10	0.2453	623.252	54890000
40114	6.8	Aug-96	37	0	0	0	0	319300	3.1E+10	0.263	660.002	56960000
40114	6.8	Jan-98	54	0	0	0	0	473100	4.9E+10	0.3797	965.253	86040000
40114	6.8	Apr-98	57	46	0	0	46	490900	5.2E+10	0.3862	992.003	90610000
40114	6.8	Jun-98	59	52	0	0	52	517100	5.4E+10	0.407	1046.5	95080000
40114	6.8	Oct-98	63	114	0	0	114	576600	5.9E+10	0.4656	1179.5	104100000
40115	15.1	Feb-95	19	0	0	0	0	1254	1.2E+08	0.00052	1.281	106700
40115	15.1	Mar-95	20	25	0	0	25	1300	1.3E+08	0.00053	1.31675	111700
40115	15.1	Jan-98	54	0	0	0	0	4227	3.9E+08	0.00182	4.41	350000
40116	16.2	Feb-95	19	0	0	0	0	1060	1E+08	0.00039	0.96875	82210
40116	16.2	Mar-95	20	0	0	0	0	1100	1.1E+08	0.00039	0.99575	86110
40116	16.2	Jan-98	54	0	0	0	0	3555	3.3E+08	0.00136	3.32	267100
40117	11.8	Feb-95	19	0	0	0	0	2154	2.5E+08	0.00084	2.3645	236400
40117	11.8	Mar-95	20	0	0	0	0	2241	2.6E+08	0.00085	2.4405	248500
40117	11.8	Jan-98	54	0	0	0	0	7205	7.9E+08	0.00294	8.085	767000
40118	11.7	Feb-95	19	0	0	0	0	5732	5.6E+08	0.00337	8.38	695500
40118	11.7	Mar-95	20	0	0	0	0	5913	5.8E+08	0.00342	8.565	723300
40118	11.7	Jan-98	54	0	0	0	0	19280	1.8E+09	0.01163	28.525	2277000
41007	6.5	Sep-91	162	38	0	0	38	169600	1.6E+10	0.1412	327.753	26390000
41007	6.5	Feb-93	163	44	16	0	60	170800	1.6E+10	0.1416	329.503	26650000
41007	6.5	Sep-94	198	70	132	0	202	231100	2.2E+10	0.1896	444.503	36240000
41024	10.8	Nov-89	149	0	0	0	0	979800	7.1E+10	0.8862	1808	112500000
41024	10.8	Aug-90	158	0	0	0	0	1073000	7.8E+10	0.9769	1985.75	122900000
41024	10.8	Oct-92	184	0	0	0	0	1355000	9.8E+10	1.233	2505	155300000
41024	10.8	Mar-95	213	0	0	0	0	1668000	1.2E+11	1.487	3050	193100000
41024	10.8	Jul-95	217	0	0	0	0	1753000	1.3E+11	1.576	3220	202000000
41024	10.8	Aug-95	218	12	0	0	12	1782000	1.3E+11	1.61	3280	204600000
41024	10.8	Nov-95	221	0	10	0	10	1822000	1.3E+11	1.64	3350	209300000
41024	10.8	Feb-96	224	0	0	0		1831000	1.4E+11	1.641	3357.5	211300000
41024	10.8	Apr-96	226	16	0	0	16	1845000	1.4E+11	1.647	3375	213500000
41024	10.8	Jun-96	228	118	0	0	118	1883000	1.4E+11	1.678	3442.5	217700000
41024	10.8	Aug-96	230	161	0	0	161	1949000	1.4E+11	1.765	3590	223700000
41024	10.8	Apr-98	250	0	398	529	927	2208000	1.7E+11	1.972	4035	255700000
41024	10.8	Jun-98	252	0	397	530	927	2255000	1.7E+11	2.015	4125	260900000
41024	10.8	Oct-98	256	0	414	529	943	2358000	1.7E+11	2.111	4322.5	271700000
81029	4.2	Oct-91	233	27	15	0	42	77130	1.1E+10	0.07199	233.31	24690000
81029	4.2	Jul-94	266	0	0	0		88660	1.3E+10	0.08181	266.91	28530000
81029	4.2	Sep-95	280	464	0	0	464	93780	1.4E+10	0.0868	282.265	30100000
81053	4.6	Oct-89	60	0	0	0	0	42140	5E+09	0.05161	201.072	13450000
81053	4.6	Jul-90	69	0	0	0	0	45760	5.7E+09	0.05401	235.673	14740000
81053	4.6	Apr-93	102	3	0	0	3	79030	9.9E+09	0.09429	400.584	25570000
81053	4.6	Nov-93	109	0	0	0		102200	1.2E+10	0.1324	471.749	32410000
81053	4.6	Dec-93	110	23	0	0	23	102500	1.2E+10	0.1324	472.503	32560000
81053	4.6	Oct-94	120	0	0	0		128300	1.5E+10	0.1683	547.44	40950000
81053	4.6	Feb-95	124	40	0	0	40	130200	1.5E+10	0.1687	551.966	41970000

Table C-2 (Cont'd) Measured Alligator Fatigue Cracking and Predicted Bottom-up Damage Using MS1 Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	1.0,1.5	1.0,2.5	1.2,0.8	1.2,1.5	1.2,2.5
81053	4.6	May-95	127	40	0	0	40	131900	1.6E+10	0.1697	567.808	42520000
81053	4.6	May-96	139	0	0	0		139300	1.7E+10	0.1754	653.055	44760000
81053	4.6	Oct-96	144	310	0	0	310	143700	1.7E+10	0.1797	717.933	45790000
81053	4.6	Nov-96	145	253	0	0	253	144100	1.7E+10	0.1799	720.196	45980000
81053	4.6	Mar-97	149	457	0	0	457	147000	1.8E+10	0.1808	726.734	47500000
91803	7.2	Jul-89	49	0	0	0	0	16630	3E+09	0.00869	31.325	4832000
91803	7.2	Sep-90	63	0	0	0	0	23090	4.1E+09	0.01218	43.675	6646000
91803	7.2	Aug-91	74	0	0	0	0	28260	5.1E+09	0.01496	53.45	8182000
91803	7.2	Sep-92	87	8	0	0	8	35010	6.4E+09	0.01815	65.7	10210000
91803	7.2	May-94	107	211	0	0	211	45520	8.7E+09	0.02278	83.9751	13610000
91803	7.2	May-95	119	240	0	0	240	53610	1E+10	0.02678	98.8251	16050000
91803	7.2	Oct-96	136	84	82	0	166	68530	1.3E+10	0.03541	128.2	20110000
91803	7.2	May-97	143	301	0	0	301	72440	1.4E+10	0.0363	133.575	21710000
91803	7.2	Sep-97	147	15	325	0	340	77760	1.5E+10	0.03975	144.85	22940000
91803	7.2	Jun-98	156	195	0	0	195	84280	1.6E+10	0.04216	155.5	25220000
120103	12	Dec-96	14	0	0	0	0	459.2	3.7E+07	0.00022	0.59125	45680
120104	18	Dec-96	14	0	0	0	0	64.47	5020000	2.2E-05	0.05558	4267
120105	7.9	Dec-96	14	0	0	0	0	2861	2.5E+08	0.00178	5.06	433300
120106	15	Dec-96	14	0	0	0	0	133.6	1.1E+07	5.1E-05	0.1317	10280
123995	5	Apr-92	197	0	0	0		1.1E+07	8.9E+11	10.73	25862.5	2.043E+09
123995	5	Mar-94	220	86	0	0		1.3E+07	1E+12	12.27	28891.9	2.331E+09
123995	5	Jan-96	242	58	0	0		1.4E+07	1.1E+12	13.7	31746	2.604E+09
123995	5	Jan-96	243	122	0	0		1.4E+07	1.1E+12	13.75	31846.2	2.618E+09
123997	3.1	Aug-90	195	2000	0	0	2000	1521000	1.6E+11	1.719	4581.87	434300000
123997	3.1	Oct-91	209	0	3000	0	3000	1696000	1.7E+11	1.909	5107.48	485300000
123997	3.1	Mar-93	226	0	4680	0	4680	1915000	2E+11	2.114	5726.72	557700000
123997	3.1	Mar-94	238	0	5047	0	5047	2086000	2.2E+11	2.307	6241.93	606600000
124105	2.3	Apr-89	53	0	0	0	0	2186000	2.6E+11	2.571	7624.95	846500000
124105	2.3	Oct-91	83	0	0	0	0	3432000	4E+11	4.101	12028.7	1.318E+09
124105	2.3	Mar-93	100	0	0	0	0	4165000	5.1E+11	4.833	14470.9	1.638E+09
124106	8.2	Apr-89	21	0	0	0	0	146600	1E+10	0.1137	263.25	17780000
124106	8.2	Feb-91	43	0	0	0	0	293400	2.1E+10	0.2218	521	36040000
124106	8.2	Jul-91	48	0	0	0	0	328000	2.3E+10	0.2486	583	40160000
124106	8.2	Mar-94	80	0	0	0	0	536400	3.9E+10	0.3959	943.5	66780000
124106	8.2	Jan-97	114	0	0	0	0	757500	5.6E+10	0.5543	1327.25	94800000
124107	2.7	Dec-89	75	0	0	0	0	220000	2.5E+10	0.2359	523.502	79760000
124107	2.7	Feb-91	89	0	0	0	0	271400	3.2E+10	0.2863	643.552	99830000
124107	2.7	Jul-91	94	0	0	0	0	290100	3.4E+10	0.3078	688.744	106200000
124107	2.7	Mar-93	114	732	355	9	1096	371200	4.4E+10	0.3856	876.484	138700000
124107	2.7	Mar-94	126	656	243	0	899	424000	5.1E+10	0.4396	1000.42	158600000
124107	2.7	Jan-96	148	264	812	93	1168	529400	6.4E+10	0.5444	1248.28	198900000
124107	2.7	Mar-97	162	44	372	1224	1640	602000	7.3E+10	0.6143	1416.51	227700000
124108	9.9	Apr-89	35	0	0	0	0	10560	6.5E+08	0.00889	16.9875	951100
124108	9.9	Jan-91	56	0	0	0	0	16920	1.1E+09	0.01441	27.225	1523000
124108	9.9	Oct-91	65	0	0	0	0	20120	1.2E+09	0.01728	32.5	1797000
124108	9.9	Mar-94	94	0	0	0	0	29320	1.9E+09	0.02466	46.85	2662000
124108	9.9	Aug-94	99	0	0	0	0	31520	2E+09	0.02668	50.575	2843000

Table C-2 (Cont'd) Measured Alligator Fatigue Cracking and Predicted Bottom-up Damage Using MS1 Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	1.0,1.5	1.0,2.5	1.2,0.8	1.2,1.5	1.2,2.5
124108	9.9	Jan-96	116	0	0	0	0	37210	2.4E+09	0.03103	59.3	3389000
124135	1.4	Dec-89	227	1112	86	0	1198	3.6E+07	5.7E+12	41.46	103280	2.284E+10
124135	1.4	Jan-91	240	2045	355	0	2400	3.8E+07	6.1E+12	43.56	108947	2.421E+10
131031	11.1	Apr-91	119	0	0	0	0	10300	1E+09	0.00616	15.46	1331000
131031	11.1	Jul-92	134	0	0	0	0	13200	1.3E+09	0.00801	20.985	1687000
131031	11.1	Jan-93	140	0	0	0	0	14210	1.4E+09	0.00864	22.8625	1816000
131031	11.1	Apr-94	155	0	0	0	0	16950	1.7E+09	0.01022	26.6	2179000
131031	11.1	Oct-94	161	0	0	0	0	18860	1.8E+09	0.0114	28.475	2412000
131031	11.1	Aug-95	171	0	0	0	0	21210	2.1E+09	0.01291	30.425	2709000
131031	11.1	Jan-96	176	0	0	0	0	22220	2.2E+09	0.0134	31.325	2851000
131031	11.1	Apr-96	179	0	0	0	0	22590	2.3E+09	0.01349	31.725	2915000
134111	8.7	Mar-89	101	0	0	0	0	49200	4.4E+09	0.05754	129.85	9844000
134111	8.7	Mar-91	125	0	0	0	0	73950	6.7E+09	0.08599	194.875	14800000
134111	8.7	Feb-92	136	316	0	0	316	86180	7.8E+09	0.1001	226.925	17240000
134112	15.9	May-89	144	0	0	0	0	45940	3E+09	0.03512	70.775	4172000
134112	15.9	Feb-91	165	0	0	0	0	56920	3.7E+09	0.04366	87.65	5178000
134112	15.9	Apr-91	167	0	0	0	0	57840	3.8E+09	0.04408	88.825	5279000
134112	15.9	Feb-94	201	0	0	0	0	79730	5.2E+09	0.06081	122.525	7251000
134112	15.9	Oct-94	209	0	0	0	0	86210	5.5E+09	0.06608	132.9	7799000
134112	15.9	Jan-96	224	0	0	0	0	95690	6.2E+09	0.07307	147.05	8707000
134112	15.9	Feb-97	237	0	0	0	0	105500	6.9E+09	0.08039	161.95	9605000
134112	15.9	Apr-98	251	0	0	0	0	116800	7.6E+09	0.08872	179.125	10640000
134113	15.2	May-89	144	0	0	0	0	74740	5.5E+09	0.05227	115.725	7795000
134113	15.2	Feb-91	165	0	0	0	0	89780	6.7E+09	0.06291	138.925	9375000
134113	15.2	Apr-91	167	0	0	0	0	90980	6.8E+09	0.06341	140.475	9530000
134113	15.2	Feb-94	201	0	0	0	0	120100	8.9E+09	0.08371	185.475	12540000
134113	15.2	Oct-94	209	0	0	0	0	128600	9.5E+09	0.08996	199.1	13370000
134113	15.2	Jan-96	224	0	0	0	0	140700	1.1E+10	0.09814	217.325	14710000
134113	15.2	Feb-97	237	47	0	0	47	153200	1.1E+10	0.1067	236.425	16030000
134113	15.2	Apr-98	251	44	0	0	44	167500	1.3E+10	0.1163	258.25	17530000
161001	3.7	Jul-89	192	0	0	0	0	4218000	7.1E+11	4.134	2885.09	1.84E+09
161001	3.7	Aug-90	205	0	0	0	0	4888000	8E+11	4.91	3208.17	2.121E+09
161001	3.7	Jun-93	239	36	0	0	36	6070000	1E+12	5.933	4078.23	2.66E+09
161001	3.7	Aug-94	253	16	0	0	16	6648000	1.1E+12	6.541	4509.01	2.897E+09
161001	3.7	May-95	262	0	0	0		7048000	1.2E+12	6.796	4727.24	3.104E+09
161001	3.7	Jul-97	288	3	611	0	615	8454000	1.4E+12	8.353	5580.29	3.694E+09
161001	3.7	Sep-98	302	0	434	99	533	8895000	1.5E+12	8.66	6087.59	3.891E+09
161009	10.4	Sep-89	180	0	0	0	0	10030	1.1E+09	0.00559	12.575	1091000
161009	10.4	Jul-90	190	0	0	0	0	10840	1.2E+09	0.00597	13.5275	1187000
161009	10.4	Jul-92	214	23	0	0	23	13150	1.4E+09	0.00724	16.3875	1444000
161009	10.4	Oct-93	229	0	0	0		14970	1.6E+09	0.00834	18.7475	1628000
161009	10.4	Jun-96	261	0	0	0		18690	2.1E+09	0.01014	23.1675	2067000
161009	10.4	Jul-97	274	4	0	4	9	20620	2.3E+09	0.01133	25.675	2269000
161021	5.9	Sep-89	48	0	0	0	0	14850	2E+09	0.01026	27.5767	3132000
161021	5.9	Oct-90	61	0	0	0	0	18690	2.6E+09	0.01295	34.8772	3932000
161021	5.9	Aug-91	71	0	0	0	0	21730	3E+09	0.01502	40.4775	4592000
161021	5.9	Aug-93	95	0	0	0	0	29200	4.1E+09	0.02002	54.1284	6227000

Table C-2 (Cont'd) Measured Alligator Fatigue Cracking and Predicted Bottom-up Damage Using MS1 Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	1.0,1.5	1.0,2.5	1.2,0.8	1.2,1.5	1.2,2.5
161021	5.9	Sep-95	120	0	0	0	0	37540	5.3E+09	0.02575	69.5294	8010000
161021	5.9	Jun-96	129	0	0	0	0	40070	5.7E+09	0.02699	73.6796	8652000
161021	5.9	Jul-97	142	0	0	0	0	44560	6.4E+09	0.03015	82.1052	9601000
169034	9.2	Jul-89	10	0	0	0	0	689.8	1E+08	0.00028	0.9005	111400
169034	9.2	Aug-90	23	0	0	0	0	1749	2.3E+08	0.00084	2.432	263200
169034	9.2	Jun-93	57	0	0	0	0	3976	5.8E+08	0.00178	5.3575	623100
169034	9.2	Aug-94	71	0	0	0	0	5084	7.2E+08	0.00236	6.955	782900
169034	9.2	May-95	80	0	0	0	0	5531	8.1E+08	0.00249	7.4625	866800
169034	9.2	Jul-97	106	25	0	0	25	7448	1.1E+09	0.00342	10.135	1156000
169034	9.2	Sep-98	120	0	0	25	25	8468	1.2E+09	0.0039	11.54	1311000
201009	11.1	Aug-88	44	10	0	0	10	1541	1.4E+08	0.00088	2.68	150700
201009	11.1	May-89	53	0	0	0		1769	1.7E+08	0.00098	3.005	176700
201009	11.1	Dec-90	72	42	0	0	42	2489	2.3E+08	0.00141	4.2925	244900
201009	11.1	Oct-91	82	1	13	0	14	2902	2.6E+08	0.00168	5.06	282800
201009	11.1	Apr-93	100	6	18	16	41	3413	3.2E+08	0.00191	5.82	339600
201009	11.1	Apr-95	124	2	54	0	56	4332	4E+08	0.00245	7.435	429000
201009	11.1	Apr-96	136	0	0	0		4770	4.5E+08	0.00268	8.1675	473200
201009	11.1	Jan-99	168	0	1643	0		6129	5.7E+08	0.00348	10.5575	602900
251003	6.6	Aug-89	180	0	0	0	0	198900	2.8E+10	0.1379	419.002	52090000
251003	6.6	Sep-90	193	0	0	0	0	216500	3.1E+10	0.1487	454.752	56900000
251003	6.6	Aug-91	204	28	0	0	28	232000	3.3E+10	0.1593	487.003	61030000
251003	6.6	Sep-92	217	56	93	0	149	253300	3.6E+10	0.1756	533.253	66370000
251003	6.6	Oct-95	254	45	75	0	121	310600	4.5E+10	0.2125	651.004	81840000
251003	6.6	Oct-96	266	1314	0	0	1314	330900	4.8E+10	0.2268	694.254	87100000
251003	6.6	Jun-98	286	1062	62	0	1125	364500	5.3E+10	0.2491	763.004	96260000
251004	9.6	Aug-89	178	0	0	0	0	60760	8.6E+09	0.03664	133.575	13320000
251004	9.6	Sep-90	191	0	0	0	0	67890	9.6E+09	0.0409	148.825	14890000
251004	9.6	Aug-91	202	0	0	0	0	73830	1E+10	0.04445	161.775	16200000
251004	9.6	Sep-92	215	0	0	0	0	82580	1.2E+10	0.04996	181.375	18080000
251004	9.6	Oct-95	252	0	0	0	0	107700	1.5E+10	0.06454	234.975	23680000
251004	9.6	Jun-97	272	56	0	0	56	122100	1.8E+10	0.0726	265	26960000
251004	9.6	Jun-98	284	0	0	0		132700	1.9E+10	0.07895	288	29280000
261001	2.2	Jul-88	203	0	0	0	0	222700	4.2E+10	0.1689	653.312	114000000
261001	2.2	Sep-89	217	0	0	0	0	237800	4.5E+10	0.1811	698.222	121400000
261001	2.2	Jul-90	227	0	0	0	0	248200	4.7E+10	0.1881	727.587	126900000
261001	2.2	Jul-91	239	33	0	0	33	260800	4.9E+10	0.1978	765.012	133300000
261001	2.2	Sep-91	241	28	0	0	28	262700	4.9E+10	0.2	770.962	133900000
261001	2.2	Sep-92	253	40	0	0	40	275800	5.2E+10	0.2092	808.963	140900000
261001	2.2	Jun-93	262	0	81	0	81	287400	5.4E+10	0.2166	841.398	147500000
261001	2.2	Jun-93	263	76	0	0	76	288200	5.4E+10	0.2179	844.469	147700000
261001	2.2	May-95	285	58	0	0	58	311800	5.9E+10	0.2347	912.218	160100000
261001	2.2	Jul-96	299	83	0	0	83	326300	6.1E+10	0.2468	956.169	167100000
261004	4.2	Sep-89	51	0	0	0	0	68840	1.1E+10	0.05051	162.731	24240000
261004	4.2	Jul-90	61	0	0	0	0	83420	1.4E+10	0.06009	196.613	29950000
271018	4.4	Apr-89	124	0	0	0	0	1007000	1.4E+11	0.8283	2436.34	292900000
271018	4.4	Jun-89	126	0	0	0	0	1042000	1.4E+11	0.8661	2531.96	301200000
271018	4.4	Oct-90	142	0	0	0	0	1247000	1.7E+11	1.047	3042.9	357800000

Table C-2 (Cont'd) Measured Alligator Fatigue Cracking and Predicted Bottom-up Damage Using MS1 Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	1.0,1.5	1.0,2.5	1.2,0.8	1.2,1.5	1.2,2.5
271018	4.4	Jun-93	174	0	0	0	0	1644000	2.3E+11	1.349	3971.2	478400000
271018	4.4	Jul-93	176	0	0	0	0	1681000	2.3E+11	1.403	4082.5	484700000
271018	4.4	Mar-94	183	0	0	0	0	1733000	2.4E+11	1.427	4186.2	503200000
271018	4.4	Aug-94	188	0	0	0	0	1841000	2.5E+11	1.536	4472.03	530600000
271087	15.7	Oct-91	154	0	0	0	0	838	9.4E+07	0.00024	0.54975	63290
271087	15.7	May-93	173	0	0	0	0	918.2	1E+08	0.00026	0.5995	69800
271087	15.7	Oct-94	190	0	3	0	3	1021	1.1E+08	0.00029	0.66725	77190
271087	15.7	Jun-96	210	13	0	0	13	1119	1.3E+08	0.00031	0.73	84960
291008	11.4	Feb-92	70	41	0	0	41	1258	1.2E+08	0.00069	1.52775	132600
291008	11.4	Mar-93	83	140	22	0	161	1497	1.4E+08	0.00081	1.74425	158500
291008	11.4							1512	1.5E+08	0.00081	1.7565	160500
291008	11.4	Apr-96	120	0	0	0		2288	2.2E+08	0.00123	2.4615	243000
291008	11.4	Feb-00	152	365	715	0		3133	3E+08	0.00169	3.275	330700
307088	4.9	Sep-89	100	0	0	0	0	109300	1.8E+10	0.08934	167.569	35380000
307088	4.9	May-91	120	0	66	0	66	133300	2.2E+10	0.1068	200.587	43780000
308129	3.2	Oct-89	17	0	0	0	0	58740	1.1E+10	0.04035	189.106	24200000
308129	3.2	Jul-91	38	0	0	0	0	167000	3.4E+10	0.1094	406.555	77630000
308129	3.2	Jul-92	50	0	0	0	0	218400	4.6E+10	0.1392	541.159	102700000
308129	3.2	Aug-93	63	0	0	0	0	274000	5.8E+10	0.1735	690.814	128500000
308129	3.2	Dec-93	67	0	0	0	0	288000	6.1E+10	0.1804	727.692	135400000
308129	3.2	Mar-94	70	0	0	0	0	308200	6.7E+10	0.1871	757.28	149200000
308129	3.2	Oct-94	77	0	0	0	0	371500	7.7E+10	0.2416	849.045	176100000
308129	3.2	Feb-95	81	0	0	0	0	392100	8.4E+10	0.2474	879.92	189800000
308129	3.2	May-95	84	0	0	0	0	404900	8.8E+10	0.2527	913.367	196400000
308129	3.2	Jun-96	97	0	0	0	0	468200	1E+11	0.2896	1078.46	226800000
308129	3.2	Oct-96	101	0	0	0	0	489300	1E+11	0.3069	1139.35	234200000
308129	3.2	Jan-97	104	0	0	0	0	501400	1.1E+11	0.3099	1165.08	242000000
308129	3.2	Mar-97	106	0	0	0	0	511300	1.1E+11	0.3126	1188.23	248400000
308129	3.2	Aug-97	111	0	0	0	0	539000	1.2E+11	0.3357	1271.85	258300000
308129	3.2	Oct-97	113	0	0	0	0	548800	1.2E+11	0.3422	1300.15	262200000
321020	7	Jul-91	86	0	0	0	0	27970	3.6E+09	0.01856	41.4501	5566000
321020	7	Aug-93	111	18	0	0	18	38560	5E+09	0.02569	57.1501	7678000
321020	7	Sep-94	123	187	62	0	250	44030	5.7E+09	0.02924	65.1751	8803000
321020	7	Apr-95	131	34	0	0	34	46700	6.3E+09	0.03025	68.4751	9499000
321020	7	Jun-97	157	672	1043	0		60580	8.1E+09	0.03937	88.9751	12250000
321020	7	Jun-98	169	3269	36	0		66800	8.9E+09	0.04314	97.8751	13540000
341031	7.3	Apr-92	224	280	12	0	292	110800	1.2E+10	0.1118	273.75	23900000
341031	7.3	Feb-93	234	598	11	0	609	122000	1.3E+10	0.1237	302.5	26220000
341031	7.3	Oct-95	266	0	652	305	957	164700	1.7E+10	0.1674	409	35190000
341031	7.3	Nov-95	267	574	8	0	581	165300	1.7E+10	0.1676	409.75	35380000
341033	7.4	Apr-92	211	79	0	0	79	40120	4.8E+09	0.02746	134.45	7118000
341033	7.4	Feb-93	221	6	0	0	6	42450	5E+09	0.02913	142.125	7517000
341033	7.4	Nov-95	254	15	0	0	15	49890	5.9E+09	0.03425	167.525	8843000
341033	7.4	Jul-97	274	0	0	0		54020	6.5E+09	0.03664	180.075	9641000
341034	11.1	Oct-89	48	0	0	0	0	4159	5E+08	0.00153	4.4175	458500
341034	11.1	Sep-90	59	0	0	0	0	5227	6.3E+08	0.00195	5.5825	574500
341034	11.1	Apr-92	78	0	0	0	0	6709	8.6E+08	0.0024	7.0025	758000

Table C-2 (Cont'd) Measured Alligator Fatigue Cracking and Predicted Bottom-up Damage Using MS1 Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	1.0,1.5	1.0,2.5	1.2,0.8	1.2,1.5	1.2,2.5
341034	11.1	Feb-93	88	0	0	0	0	7861	9.9E+08	0.00286	8.2625	879200
341034	11.1	Nov-95	121	0	0	0	0	11890	1.5E+09	0.00438	12.575	1319000
341034	11.1	Jul-97	141	129	75	0	205	14300	1.8E+09	0.00521	15.0425	1597000
350101	7.2	May-97	19	0	0	0	0	132200	1.4E+10	0.1239	317.75	28550000
350102	4.8	May-97	19	0	0	0	0	432100	5.7E+10	0.3899	1168.9	136000000
350103	12.5	May-97	19	0	0	0	0	47170	4.1E+09	0.03855	90.95	6949000
350104	19.2	May-97	19	0	0	0	0	5895	4.8E+08	0.00341	7.785	561800
350105	9.9	May-97	19	0	0	0	0	161900	1.3E+10	0.1717	366.5	25260000
350106	15.6	May-97	19	0	0	0	0	11690	1E+09	0.00738	17.0275	1293000
351005	8.9	Oct-89	73	0	0	0	0	8037	1E+09	0.00439	12.755	1386000
351005	8.9	Mar-91	90	0	0	0	0	10080	1.4E+09	0.00528	15.6625	1790000
351005	8.9	Oct-92	109	0	0	0	0	13730	1.8E+09	0.00725	21.4625	2412000
351005	8.9	Feb-94	125	0	0	0	0	16750	2.3E+09	0.00878	26.025	2969000
351005	8.9	Mar-95	138	0	0	0	0	20040	2.7E+09	0.01071	31.35	3521000
351005	8.9	Apr-97	163	0	0	0	0	26690	3.6E+09	0.01381	41.25	4763000
351022	6.3	Oct-89	37	0	0	0	0	16930	2.3E+09	0.01127	23.5704	3941000
351022	6.3	Mar-91	54	0	0	0	0	26780	3.8E+09	0.01773	36.9006	6385000
351022	6.3	Oct-92	73	0	0	0	0	42680	5.9E+09	0.02893	59.3759	9972000
351022	6.3	Feb-94	89	0	0	0	0	55420	8E+09	0.03682	76.2512	13210000
351022	6.3	Mar-95	102	0	0	0	0	68410	9.9E+09	0.04511	93.8765	16320000
351022	6.3	Apr-97	127	0	0	0	0	97080	1.4E+10	0.06538	134.002	23010000
351112	6.3	Dec-89	67	0	0	0	0	154000	1.3E+10	0.1709	370.006	26670000
351112	6.3	Jan-91	80	0	0	0	0	180900	1.6E+10	0.1962	430.257	31640000
351112	6.3	Mar-91	82	0	0	0	0	183800	1.6E+10	0.1975	435.007	32330000
351112	6.3	Jan-93	104	0	0	0	0	232200	2E+10	0.2494	549.259	40820000
351112	6.3	Feb-94	117	0	0	0	0	260800	2.3E+10	0.2797	616.01	45930000
351112	6.3	Oct-94	125	0	0	0	0	284100	2.5E+10	0.3083	675.01	49560000
351112	6.3	Mar-95	130	9	0	0	9	290000	2.6E+10	0.3105	684.511	51140000
351112	6.3	Apr-95	131	0	0	0	0	292300	2.6E+10	0.3122	689.261	51590000
351112	6.3	Jun-95	133	0	0	0	0	298600	2.6E+10	0.3194	705.011	52570000
351112	6.3	Nov-96	150	0	0	0	0	338900	3E+10	0.3617	799.512	59510000
351112	6.3	Apr-97	155	0	0	0	0	344400	3.1E+10	0.3639	808.263	61000000
351112	6.3	Sep-97	160	0	0	0	0	361400	3.2E+10	0.3862	853.013	63450000
371024	4.8	Nov-89	109	167	0	0	167	25410	3E+09	0.02372	116.664	6448000
371024	4.8	Mar-91	125	889	89	0		29720	3.6E+09	0.02706	135.619	7666000
371024	4.8	Apr-92	138	1442	308	342		33810	4.2E+09	0.03051	153.998	8777000
371802	4.5	Mar-91	66	36	0	0	36	1333000	1.4E+11	2.224	5369.23	533500000
371802	4.5	Oct-92	85	51	36	0	86	1746000	1.8E+11	2.979	7146.37	688600000
371802	4.5	Apr-94	103	1521	0	0	1521	2089000	2.3E+11	3.464	8472.29	841200000
371802	4.5	Jul-95	118	1739	70	0	1809	2421000	2.6E+11	4.091	9921.74	965700000
371802	4.5	Apr-96	127	2608	206	0	2814	2589000	2.8E+11	4.319	10557	1.043E+09
371992	2.4	Mar-91	14	0	0	0	0	137800	2.1E+10	0.114	397	55870000
371992	2.4	Oct-92	33	2	0	0	2	343100	4.7E+10	0.321	1022.56	129900000
371992	2.4	Apr-94	51	0	0	0	0	572300	8.6E+10	0.5025	1670.26	229100000
371992	2.4	Feb-96	73	0	0	0	0	896300	1.4E+11	0.7799	2607.42	362700000
404087	10.1	Jan-90	43	0	0	0	0	16340	1.2E+09	0.0218	21.355	2639000
404087	10.1	Oct-91	64	0	0	0	0	26260	1.9E+09	0.03463	34.8	4235000

Table C-2 (Cont'd) Measured Alligator Fatigue Cracking and Predicted Bottom-up Damage Using MS1 Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	1.0,1.5	1.0,2.5	1.2,0.8	1.2,1.5	1.2,2.5
404087	10.1	Nov-92	77	0	0	0	0	32210	2.3E+09	0.04169	42.625	5238000
404087	10.1	Feb-93	80	0	0	0	0	32480	2.4E+09	0.04174	42.9	5320000
404087	10.1	Nov-94	101	0	0	0	0	44590	3.3E+09	0.05645	59	7309000
404087	10.1	Feb-95	104	32	0	0	32	44870	3.4E+09	0.05649	59.225	7396000
404087	10.1	Aug-95	110					50750	3.8E+09	0.06532	67.35	8270000
404087	10.1	Jun-97	132	67	207	0	273	64650	4.9E+09	0.08207	86.05	10600000
404163	11.5	Jan-90	34	0	0	0	0	18100	1.4E+09	0.01439	31.225	2117000
404163	11.5	Mar-91	48	0	0	0	0	24120	2E+09	0.0189	41.2	2851000
404163	11.5	Oct-91	55	0	0	0	0	28690	2.3E+09	0.02245	49.1	3361000
404163	11.5	Nov-92	68	0	0	0	0	34920	2.8E+09	0.02769	59.975	4081000
404163	11.5	Mar-93	72	0	0	0	0	35420	3E+09	0.02776	60.375	4184000
404163	11.5	Nov-94	92	0	0	0	0	45900	3.8E+09	0.03586	78.15	5397000
404163	11.5	Apr-96	109	27	0	0	27	51660	4.4E+09	0.03952	87	6157000
404163	11.5	Aug-97	125					61420	5.1E+09	0.04839	104.825	7213000
404163	11.5	Jan-99	141	13	0	0	13	68290	5.7E+09	0.05328	115.925	8049000
404165	8.1	Jan-90	68	0	0	0	0	41420	4.1E+09	0.02849	67.9	5613000
404165	8.1	Mar-91	82	0	0	0	0	49630	5.1E+09	0.03339	80.55	6825000
404165	8.1	Oct-91	89	0	0	0	0	55840	5.5E+09	0.0381	91.375	7569000
404165	8.1	Nov-92	102	0	0	0	0	63170	6.4E+09	0.04238	102.575	8656000
404165	8.1	Mar-93	106	0	0	0	0	64080	6.7E+09	0.0425	103.375	8882000
404165	8.1	Oct-94	125	1	2	0	3	79260	7.9E+09	0.05432	129.6	10780000
404165	8.1	Nov-94	126	0	0	0		79540	8E+09	0.05436	129.85	10840000
404165	8.1	Apr-95	131	3	0	0	3	81230	8.4E+09	0.05475	131.675	11200000
404165	8.1	Jun-95	133	3	0	0	3	83120	8.5E+09	0.05589	134.75	11440000
404165	8.1	Apr-96	143	0	0	0		89400	9.3E+09	0.05985	144.525	12350000
404165	8.1	Nov-96	150	0	0	0		95780	9.7E+09	0.06471	155.6	13120000
404165	8.1	May-97	156	32	0	0	32	98000	1E+10	0.06537	158.175	13560000
404165	8.1	Sep-97	160	40	0	0	40	102600	1E+10	0.06896	166.375	14080000
421599	12.3	Aug-89	25	0	0	0	0	9166	9.1E+08	0.00524	12.545	1105000
421599	12.3	Sep-90	38	0	0	0	0	12360	1.3E+09	0.00657	19.115	1492000
421599	12.3	Mar-93	68	0	0	0	0	19560	2.2E+09	0.0094	33.525	2427000
421599	12.3	Sep-94	86	0	0	0	0	25390	2.9E+09	0.01211	47.45	3089000
421599	12.3	Jun-95	95	0	0	0	0	27670	3.2E+09	0.0128	51.55	3421000
421599	12.3	Jul-96	108	0	0	0	0	31950	3.7E+09	0.01468	61.25	3929000
421599	12.3	Mar-98	128	9	0	0	9	38720	4.6E+09	0.01751	75.475	4790000
451011	3.2	Mar-92	69	0	0	0	0	1044000	1.3E+11	0.9784	2818.14	315100000
451011	3.2	Oct-92	76	0	0	0	0	1159000	1.4E+11	1.11	3154.76	344200000
451011	3.2	Jun-93	84	1101	0	0	1101	1274000	1.6E+11	1.181	3426.2	387400000
451011	3.2	Jan-96	115	11	46	0	57	1757000	2.2E+11	1.643	4742.65	531400000
451011	3.2	Jun-97	132	1729	41	150	1919	2015000	2.5E+11	1.86	5411.59	614600000
451011	3.2	Feb-99	150	1203	612	254	2070	2299000	2.9E+11	2.122	6179.16	701300000
473104	1.3	Aug-89	39	0	74	0		19400	3.8E+09	0.01938	336.803	15270000
473104	1.3	Nov-89	42	0	0	0		20300	4E+09	0.02005	369.765	15900000
473104	1.3	May-91	60	52	0	0		30350	6.4E+09	0.0268	612.392	24720000
473104	1.3	Aug-91	63	451	0	0		30730	6.5E+09	0.02725	635.936	24860000
473104	1.3	Oct-92	77	140	19	0		36610	7.8E+09	0.03155	816.357	29510000
473104	1.3	Aug-93	87	370	0	0		42540	9.1E+09	0.0359	976.456	34590000

Table C-2 (Cont'd) Measured Alligator Fatigue Cracking and Predicted Bottom-up Damage Using MS1 Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	1.0,1.5	1.0,2.5	1.2,0.8	1.2,1.5	1.2,2.5
473104	1.3	Nov-95	114	124	300	292		60820	1.3E+10	0.04919	1527.14	50540000
473104	1.3	Oct-96	125	159	1217	407		69330	1.5E+10	0.05585	1768.77	57890000
480001	2.4	Apr-89	1	0	0	0	0	37620	3.4E+09	0.06372	225.736	15520000
480001	2.4	Oct-90	19	0	0	0	0	700000	6.1E+10	1.451	4396.98	270400000
480001	2.4	May-91	26	0	0	0	0	970900	9.6E+10	1.8	5847.47	407700000
480001	2.4	Feb-93	47	0	0	0	0	1876000	1.9E+11	3.498	11269.5	797900000
480001	2.4	Apr-93	49	0	0	0	0	1971000	2E+11	3.62	11781.3	845700000
480001	2.4	Feb-95	71	0	0	0	0	3116000	3.3E+11	5.596	18476.4	1.361E+09
480001	2.4	Mar-95	72	0	0	0	0	3168000	3.4E+11	5.649	18727.6	1.391E+09
480001	2.4	May-97	98	0	18	0	18	4827000	5.2E+11	8.543	28491.7	2.129E+09
480001	2.4	Mar-98	108	0	27	0	27	5527000	6.1E+11	9.699	32463.3	2.465E+09
481060	7.5	Jun-90	52	0	0	0	0	151300	1.8E+10	0.08844	267.75	28330000
481060	7.5	Feb-91	60	0	0	0	0	175600	2.1E+10	0.1025	309.75	32980000
481060	7.5	Apr-91	62	0	0	0	0	181000	2.1E+10	0.1044	317.75	34210000
481060	7.5	Mar-92	73	0	0	0	0	219200	2.6E+10	0.126	384.25	41420000
481060	7.5	Feb-93	84	8	0	0	8	260900	3.1E+10	0.15	457.25	49230000
481060	7.5	Mar-93	85	0	0	0	0	263900	3.1E+10	0.151	461.5	49900000
481060	7.5	Oct-94	104	0	0	0	0	343300	4E+10	0.1975	601.5	64510000
481060	7.5	Feb-95	108	0	0	0	0	351400	4.2E+10	0.1992	611	66760000
481060	7.5	Mar-95	109	0	0	0	0	354000	4.3E+10	0.1999	614.5	67440000
481060	7.5	Mar-95	112	0	0	0	0	370000	4.5E+10	0.2089	642.75	70360000
481060	7.5	Jun-95	134	0	0	0	0	466900	5.7E+10	0.2603	806	89310000
481060	7.5	Apr-97	137	0	0	0	0	487700	5.9E+10	0.2741	845.25	92780000
481060	7.5	Jul-97	139	12	0	0	12	502300	6E+10	0.2848	873.75	95060000
481060	7.5	Sep-97	154	0	0	0	0	575300	7E+10	0.3224	995.25	109500000
481077	5.1	Apr-89	88	0	0	0	0	92140	1.6E+10	0.0495	226.056	23810000
481077	5.1	Nov-91	119	0	0	0	0	129200	2.2E+10	0.07025	316.073	33020000
481077	5.1	Oct-92	130	0	0	0	0	142400	2.5E+10	0.07684	346.605	36520000
481077	5.1	May-93	137	0	0	0	0	148500	2.6E+10	0.0788	358.367	38620000
481077	5.1	Oct-94	154	10	0	0	10	171600	3E+10	0.0926	415.675	44060000
481077	5.1	Mar-95	159	0	0	0	0	175600	3.1E+10	0.09338	422.432	45620000
481077	5.1	Apr-95	160	0	0	0	0	176800	3.1E+10	0.09386	425.185	45980000
481077	5.1	Jun-95	162	0	0	0	0	180300	3.2E+10	0.09588	433.944	46710000
481077	5.1	Aug-95	164	0	0	0	0	184100	3.2E+10	0.09918	444.955	47340000
481077	5.1	Jun-96	174	0	0	0	0	195300	3.5E+10	0.1043	469.731	50610000
481077	5.1	May-97	185	13	0	0	13	208700	3.7E+10	0.1107	500.012	54380000
481077	5.1	Jul-97	187	56	0	0	56	212500	3.8E+10	0.1134	510.522	55100000
481077	5.1	Sep-97	189	50	0	0	50	216300	3.8E+10	0.1159	520.282	55820000
481077	5.1	Mar-98	195	41	0	0	41	221100	4E+10	0.1169	528.29	57780000
481109	6.5	Jan-90	68	0	0	0	0	99290	5.4E+09	0.2033	349.253	16790000
481109	6.5	Sep-90	76	0	0	0	0	115000	6.2E+09	0.2369	406.003	19360000
481109	6.5	May-91	84	0	0	0	0	124400	6.9E+09	0.2485	432.753	21290000
481109	6.5	Feb-93	105	73	0	0	73	161100	9E+09	0.322	559.754	27490000
481109	6.5	Jul-93	110	0	0	0		172200	9.6E+09	0.3443	599.005	29350000
481109	6.5	Feb-95	129	0	0	0		205100	1.2E+10	0.405	708.505	35180000
481109	6.5	May-95	132	74	0	0	74	210600	1.2E+10	0.4129	725.506	36250000
481109	6.5	Aug-96	147	150	0	0	150	246100	1.4E+10	0.4864	851.007	42070000

Table C-2 (Cont'd) Measured Alligator Fatigue Cracking and Predicted Bottom-up Damage Using MS1 Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	1.0,1.5	1.0,2.5	1.2,0.8	1.2,1.5	1.2,2.5
481130	2.7	Apr-89	200	0	0	0	0	3335000	3.4E+11	5.727	14931.6	1.227E+09
481130	2.7	Oct-90	218	0	0	0	0	3724000	3.7E+11	6.473	16793.1	1.357E+09
481130	2.7	Mar-91	223	490	44	0	534	3824000	3.9E+11	6.562	17151.4	1.408E+09
481130	2.7	Mar-92	235	830	26	0	856	4092000	4.1E+11	6.998	18326	1.511E+09
481169	1.1	Feb-90	211	0	0	0	0	3988000	7.6E+11	3.364	13280.5	2.444E+09
481169	1.1	Mar-90	212	0	0	0	0	4013000	7.7E+11	3.378	13357.8	2.462E+09
481169	1.1	Sep-90	218	0	0	0	0	4123000	7.8E+11	3.506	13749.6	2.511E+09
481169	1.1	Jan-91	222	0	0	0	0	4223000	8.1E+11	3.562	14051.6	2.589E+09
481169	1.1	Mar-91	224	0	0	0	0	4273000	8.2E+11	3.589	14208.8	2.627E+09
481169	1.1	Jun-91	227	0	0	0	0	4331000	8.3E+11	3.651	14415.9	2.656E+09
481169	1.1	Jan-92	234	0	0	0	0	4478000	8.5E+11	3.776	14902.5	2.747E+09
481169	1.1	Feb-93	247	0	0	0	0	4763000	9.1E+11	4.01	15855.7	2.924E+09
481169	1.1	Aug-93	253	0	0	0	0	4885000	9.3E+11	4.134	16279.9	2.987E+09
481169	1.1	Mar-95	272	0	0	0	0	5331000	1E+12	4.468	17729.8	3.283E+09
481169	1.1	Jul-95	276	0	0	0	0	5411000	1E+12	4.558	18009.2	3.319E+09
481169	1.1	Jul-97	300	0	0	0	0	5957000	1.1E+12	5.009	19820.9	3.661E+09
481174	4.7	Oct-90	186	0	0	0	0	943000	7.4E+10	1.117	2491.01	169200000
481174	4.7	Feb-91	190	0	0	0	0	966900	7.7E+10	1.133	2532.93	175000000
481174	4.7	Apr-91	192	0	16	0	16	980400	7.8E+10	1.145	2558.03	177600000
481174	4.7	Mar-92	203	0	0	0		1049000	8.4E+10	1.226	2706.14	189800000
481174	4.7	Feb-93	214	22	0	0	22	1115000	8.9E+10	1.301	2846.72	202200000
481174	4.7	Mar-93	215	58	0	0	58	1121000	9E+10	1.305	2856.76	203600000
481174	4.7	Feb-95	238	28	0	0	28	1261000	1E+11	1.468	3155.49	229300000
481174	4.7	Mar-95	239	109	0	0	109	1267000	1E+11	1.472	3168.05	230800000
481174	4.7	Jan-96	249	154	0	0	154	1330000	1.1E+11	1.55	3306.11	241500000
481174	4.7	Apr-97	264	492	6	0	498	1425000	1.1E+11	1.654	3506.94	259000000
481174	4.7	Mar-98	275	422	61	0	483	1490000	1.2E+11	1.726	3639.99	271800000
481178	8.5	Apr-89	10	0	0	0	0	968.6	7.3E+07	0.00092	1.93325	130100
481178	8.5	Feb-91	32	0	0	0	0	3461	2.4E+08	0.00348	7.07	445200
481178	8.5	May-91	33	0	0	0	0	3559	2.5E+08	0.00353	7.2375	460600
481178	8.5	Feb-93	56	0	0	0	0	6334	4.6E+08	0.00624	12.8025	830000
481178	8.5	Jul-93	61	0	0	0	0	7120	5.1E+08	0.00708	14.465	924500
481178	8.5	Feb-95	80	9	0	0	9	9911	7.3E+08	0.00967	19.975	1301000
481178	8.5	Mar-95	81	9	0	0	9	10040	7.4E+08	0.00975	20.1925	1322000
481183	5.7	Sep-90	188	0	0	0	0	452200	3.8E+10	0.8522	2052.26	116100000
481183	5.7	Mar-91	194	0	79	0	79	466900	4E+10	0.8614	2083.01	122000000
481183	5.7	Oct-91	201	0	0	0		529200	4.4E+10	1.005	2382.3	135400000
481183	5.7	Nov-91	202	0	0	0		532000	4.4E+10	1.007	2387.55	136600000
481183	5.7	Jan-93	216	24	0	0	24	615500	5.3E+10	1.145	2705.34	159700000
481183	5.7	Jul-93	222	9	0	40	48	667300	5.6E+10	1.241	2920.37	172600000
481183	5.7	Apr-94	231	9	9	60	78	723000	6.2E+10	1.335	3130.39	188700000
483749	1.8	Oct-90	116	0	0	0	0	1.3E+07	1.5E+12	21.93	61826.5	6.737E+09
483749	1.8	Apr-91	122	0	0	0	0	1.4E+07	1.7E+12	22.62	64528.8	7.178E+09
483749	1.8	Aug-91	126	0	0	0	0	1.4E+07	1.7E+12	23.52	66718.6	7.35E+09
483749	1.8	Mar-92	133	0	0	0	0	1.5E+07	1.8E+12	24.47	70073.1	7.826E+09
483749	1.8	Feb-93	144	55	132	41	228	1.6E+07	2E+12	26.33	75594.2	8.467E+09
483749	1.8	Mar-93	145	47	75	0	123	1.6E+07	2E+12	26.47	76083.4	8.536E+09

Table C-2 (Cont'd) Measured Alligator Fatigue Cracking and Predicted Bottom-up Damage Using MS1 Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	1.0,1.5	1.0,2.5	1.2,0.8	1.2,1.5	1.2,2.5
483749	1.8	Feb-95	168	210	172	177	559	1.8E+07	2.3E+12	30.24	87451.6	9.907E+09
483749	1.8	Mar-95	169	41	1045	0	1086	1.9E+07	2.3E+12	30.36	87894.2	9.981E+09
483749	1.8	Mar-97	193	115	343	1504	1962	2.1E+07	2.7E+12	34.29	99891.5	1.142E+10
489005	1.2	Oct-90	50	126	0	0	126	7220000	1E+12	13.01	42748.9	5.79E+09
489005	1.2	Mar-91	55	19	0	0	19	8041000	1.2E+12	14.13	47252.8	6.587E+09
489005	1.2	Aug-91	60	75	0	0	75	8783000	1.3E+12	15.37	51557.5	7.214E+09
489005	1.2	Feb-93	78	24	0	0	24	1.1E+07	1.7E+12	19.88	66985	9.4E+09
489005	1.2	Apr-93	80	58	0	0	58	1.2E+07	1.8E+12	20.28	68876.1	9.777E+09
489005	1.2	Feb-95	102	0	0	0		1.5E+07	2.3E+12	25.48	87389	1.259E+10
489005	1.2	Feb-96	114	165	0	0	165	1.7E+07	2.6E+12	28.54	98188.2	1.422E+10
489005	1.2	Jul-96	119	202	0	0	202	1.8E+07	2.8E+12	29.76	103040	1.503E+10
489005	1.2	Jul-97	131	140	0	0	140	2E+07	3.1E+12	32.73	113591	1.66E+10
489005	1.2	Jul-98	143	110	0	0	110	2.1E+07	3.3E+12	35.7	124042	1.812E+10
501002	8.5	Aug-89	58	0	0	0		1703	2.7E+08	0.00078	2.55	338300
501002	8.5	Aug-90	70	0	0	0		2083	3.3E+08	0.00096	3.13	413000
501002	8.5	May-94	115	795	0	0		3450	5.6E+08	0.00153	5.0975	697700
501002	8.5	Aug-94	118	306	0	0		3628	5.8E+08	0.00164	5.41	724700
501002	8.5	Apr-95	126	692	0	0		3798	6.2E+08	0.00168	5.6025	769300
501002	8.5	Oct-96	144	41	301	0		4519	7.3E+08	0.00203	6.72	904500
501002	8.5	May-97	151	121	31	0		4673	7.7E+08	0.00207	6.895	945300
501002	8.5	Oct-97	156	667	121	0		4959	8E+08	0.00223	7.3775	991900
501002	8.5	Jun-98	164	85	632	0		5203	8.5E+08	0.00232	7.7025	1048000
501004	8	Apr-93	102	46	0	0	46	3373	6.3E+08	0.00141	6.685	736400
501004	8	Oct-95	132	34	0	0	34	5340	9.7E+08	0.00227	10.995	1141000
501004	8	Nov-97	157	391	674	0		7230	1.3E+09	0.00309	15.08	1539000
511002	5.7	Apr-89	115	127	229	30	386	730300	9.6E+10	0.7124	2078.51	229100000
511023	10.1	Oct-89	107	0	0	0	0	37800	3.6E+09	0.02664	65.45	5326000
511023	10.1	Mar-91	124	0	0	0	0	43290	4.2E+09	0.03022	74.475	6157000
511023	10.1	May-92	138	0	0	0	0	48800	4.8E+09	0.03366	83.575	6974000
511023	10.1	Oct-92	143	13	0	0	13	52620	5E+09	0.03709	91.025	7428000
511023	10.1	Dec-93	157	11	0	0	11	58350	5.6E+09	0.04094	100.65	8264000
511023	10.1	Sep-95	178	61	0	0	61	69030	6.6E+09	0.0486	119.325	9752000
511023	10.1	Feb-96	183	182	0	0	182	69930	6.8E+09	0.04882	120.3	9940000
511023	10.1	Mar-97	196	276	0	0	276	75480	7.4E+09	0.05222	129.3	10780000
512021	7.5	Oct-89	54	0	0	0	0	48350	4.7E+09	0.04064	100	8491000
512021	7.5	Mar-91	71	31	0	0	31	62770	6.5E+09	0.05156	127.95	11290000
512021	7.5	Oct-92	90	0	0	0		85530	8.5E+09	0.07142	176.1	15150000
531008	3.4	Jul-91	153	11	17	5	33	255800	4.7E+10	0.1678	596.213	98680000
531008	3.4	Jun-93	176	25	24	6	55	299300	5.6E+10	0.1937	694.554	116100000
531008	3.4	Jun-94	188	135	439	414	988	323400	6E+10	0.2093	750.407	125500000
561007	2.8	Jul-90	121	0	0	0	0	96590	1.9E+10	0.06642	245.627	41950000
561007	2.8	May-91	131	0	0	0	0	104600	2E+10	0.07094	264.855	45730000
561007	2.8	Aug-91	134	0	0	0	0	106800	2E+10	0.074	271.846	46240000
561007	2.8	Aug-93	158	0	0	0	0	125800	2.4E+10	0.08716	320.373	54490000
561007	2.8	Oct-93	160	0	0	0	0	127200	2.4E+10	0.08808	323.952	55100000
561007	2.8	Dec-93	162	5	0	0	5	128500	2.5E+10	0.08844	326.615	55800000
561007	2.8	Mar-94	165	8	0	0	8	130900	2.5E+10	0.08926	331.942	57240000

Table C-2 (Cont'd) Measured Alligator Fatigue Cracking and Predicted Bottom-up Damage Using MS1 Model.

Section	Total Asphalt Thickness	Date	Time	Measured Alligator Cracking (ft^2)				Predicted Bottom-Up Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	1.0,1.5	1.0,2.5	1.2,0.8	1.2,1.5	1.2,2.5
561007	2.8	Apr-94	166	0	0	0		132000	2.6E+10	0.08985	334.523	57800000
561007	2.8	Aug-94	170	6	0	0	6	135300	2.6E+10	0.09308	343.845	58840000
561007	2.8	Feb-95	176	0	0	0		140100	2.7E+10	0.09521	354.666	61360000
561007	2.8	May-95	179	0	0	0		142700	2.8E+10	0.09683	361.241	62520000
561007	2.8	Sep-95	183	0	0	0		145800	2.8E+10	0.1	370.147	63450000
561007	2.8	Jun-96	192	12	0	0	12	153000	3E+10	0.1038	387.127	66990000
561007	2.8	Oct-96	196	0	0	0		155900	3E+10	0.107	395.534	67870000
561007	2.8	Nov-96	197	0	0	0		156600	3E+10	0.1073	396.949	68210000
561007	2.8	Mar-97	201	0	0	0		160100	3.1E+10	0.1085	404.607	70260000
561007	2.8	Aug-97	206	0	0	0		163900	3.2E+10	0.1129	415.843	71370000
561007	2.8	Sep-97	207	0	0	0		164700	3.2E+10	0.1136	418.008	71610000

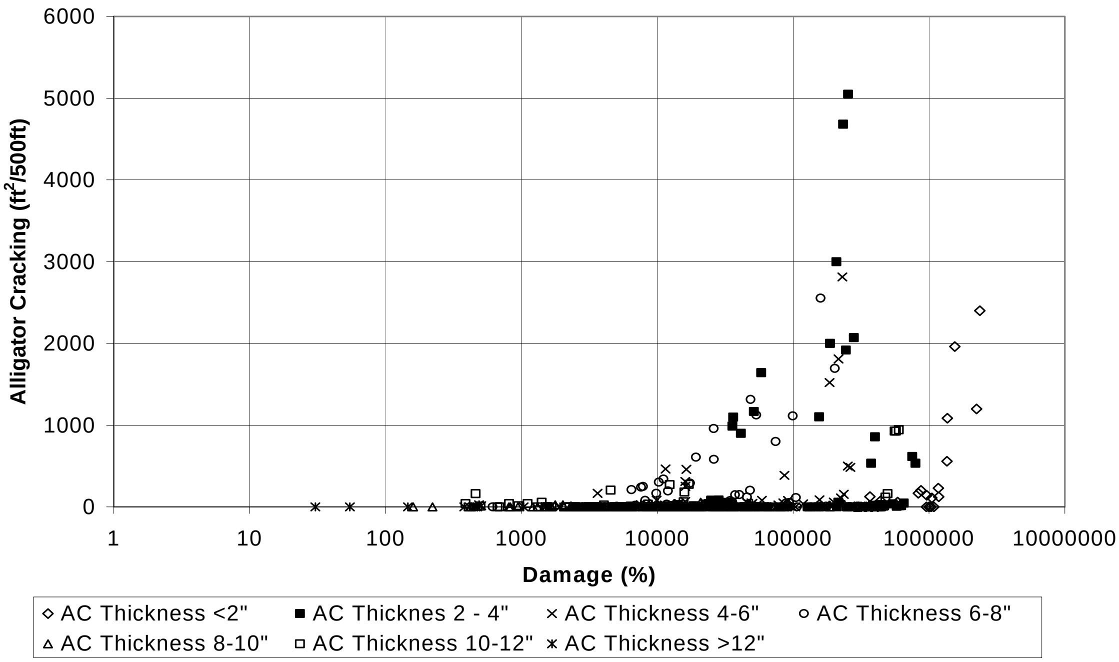

Figure C-1 Alligator Cracking vs. Predicted Bottom-Up Damage (AC 1,0.8,0.8)

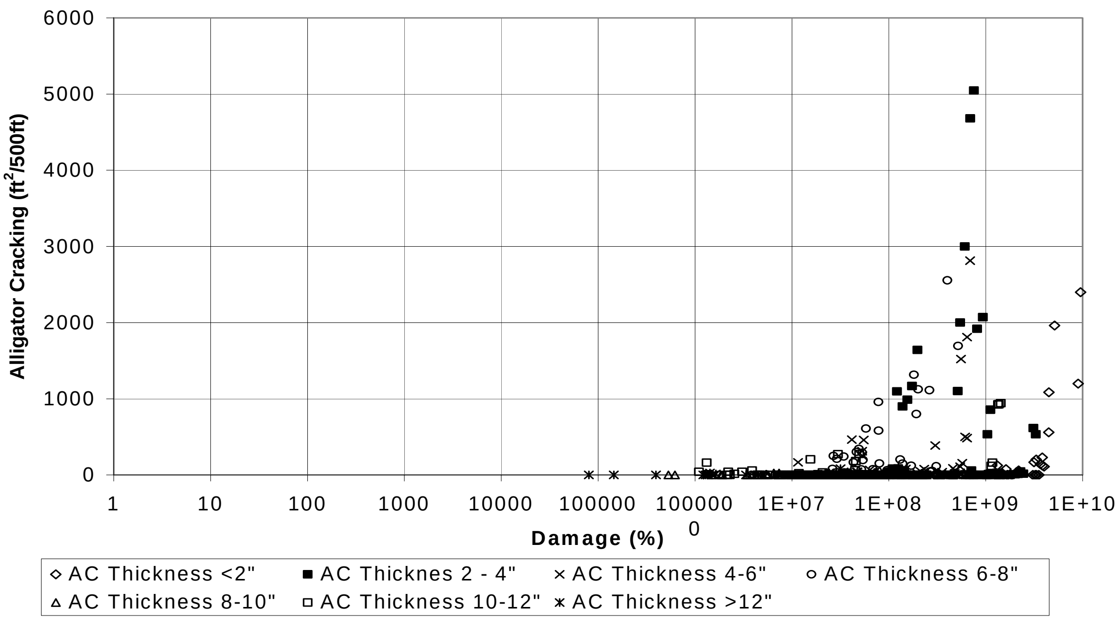

Figure C-2 Alligator Cracking vs. Predicted Bottom-Up Damage (AC 1, 0.8,1.5)

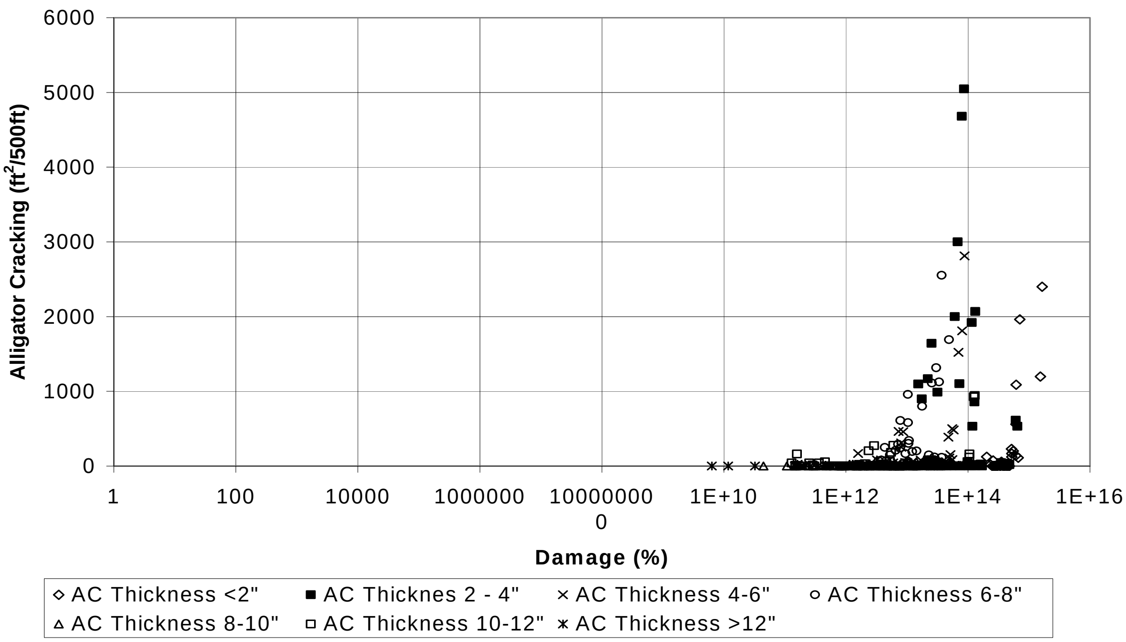

Figure C-3 Alligator Cracking vs. Predicted Bottom-Up Damage (AC 1, 0.8,2.5)

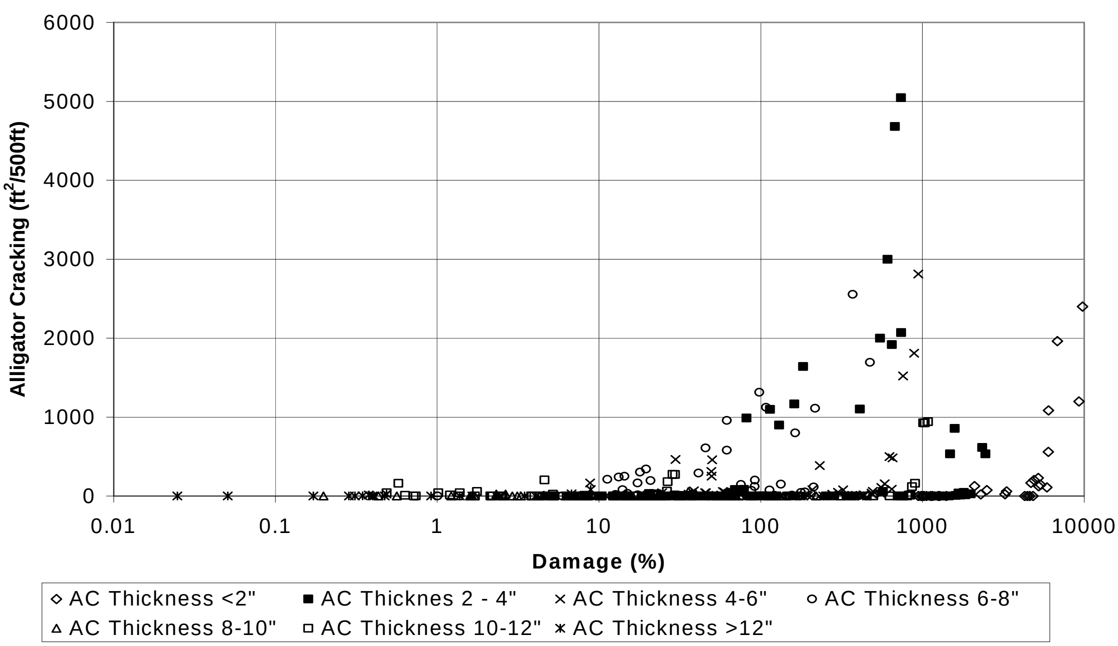

Figure C-4 Alligator Cracking vs. Predicted Bottom-Up Damage (AC 1,1.0, 0.8)

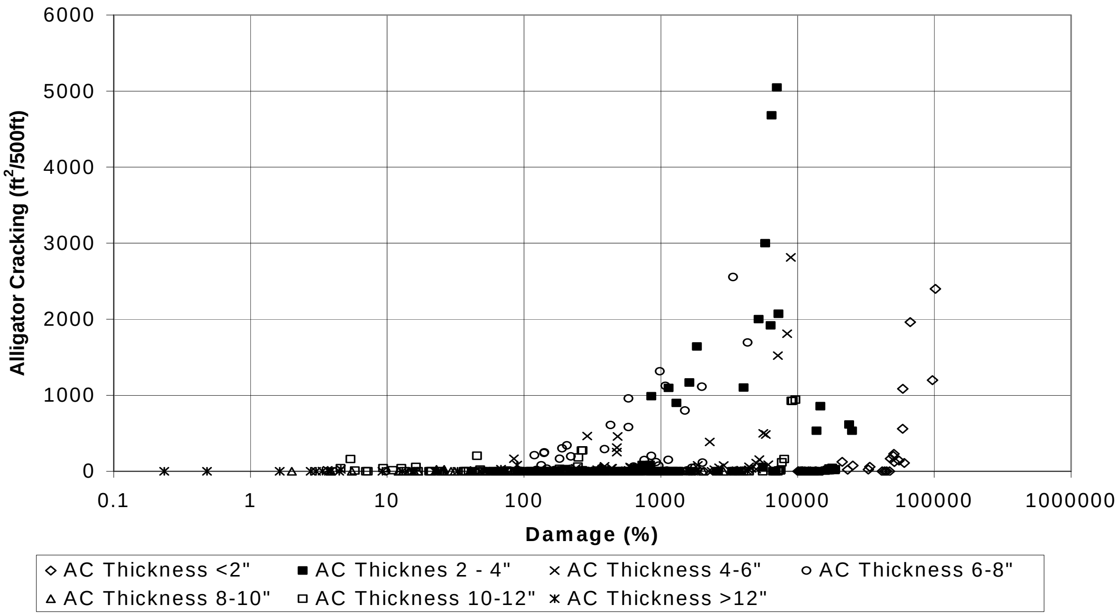

Figure C-5 Alligator Cracking vs. Predicted Bottom-Up Damage (AC 1,1.0,1.0)

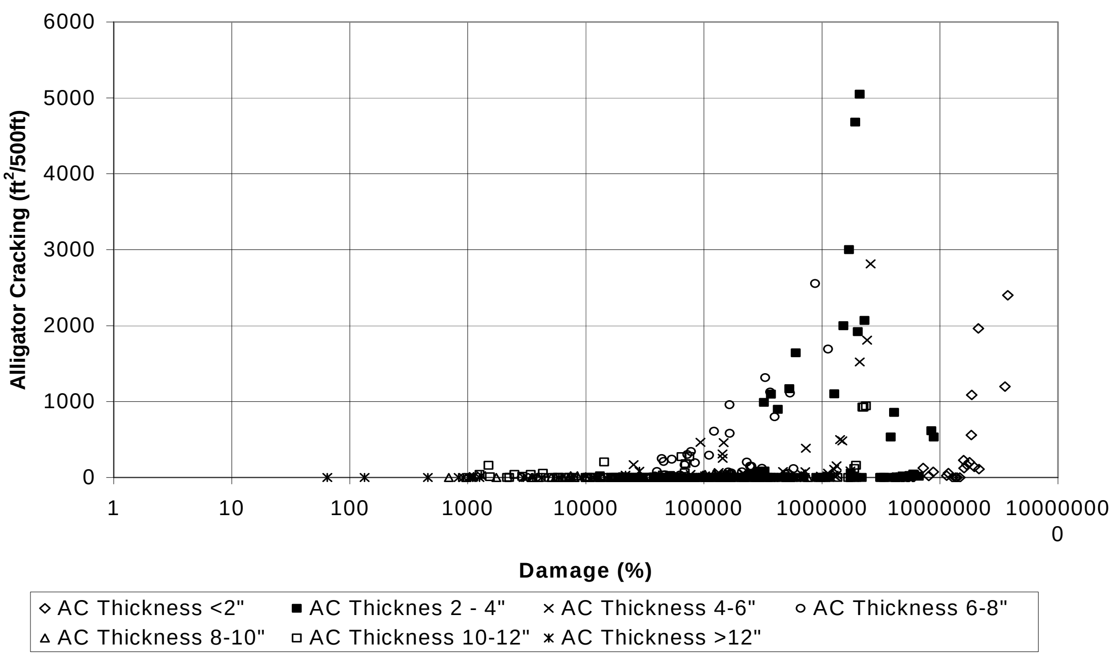

Figure C-6 Alligator Cracking vs. Predicted Bottom-Up Damage (AC 1,1.0,1.5)

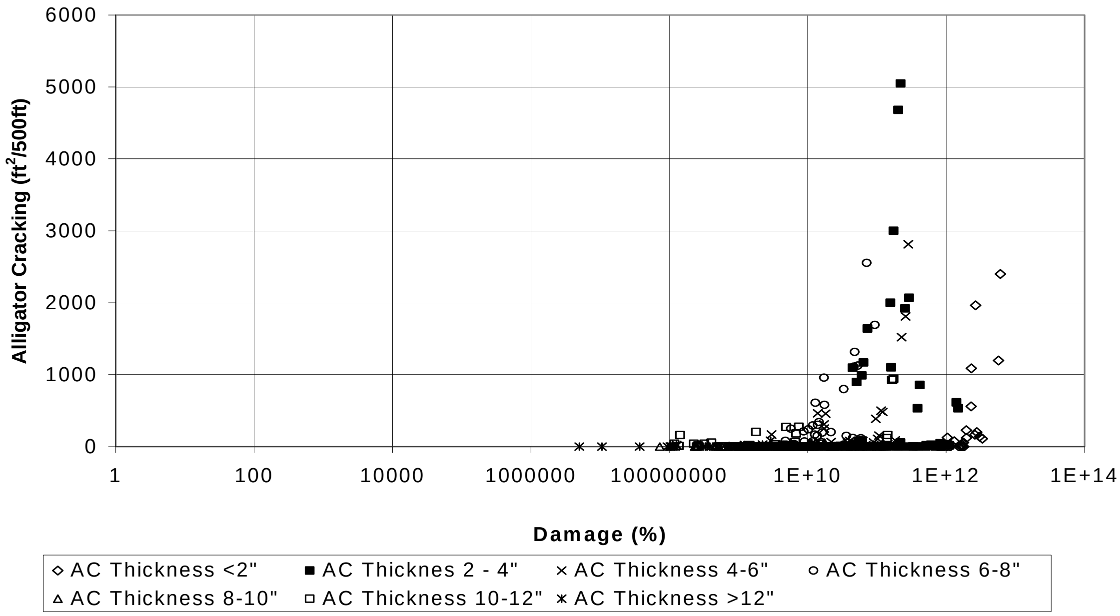

Figure C-7 Alligator Cracking vs. Predicted Bottom-Up Damage (AC 1,1.0,2.5)

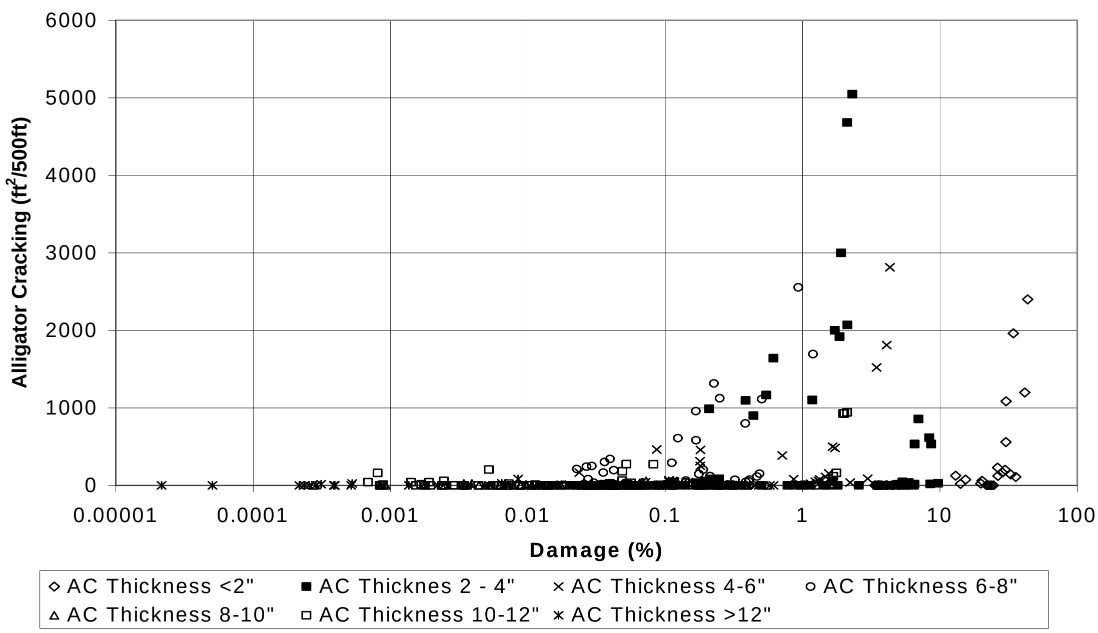

Figure C-8 Alligator Cracking vs. Predicted Bottom-Up Damage (AC 1,1.2, 0.8)

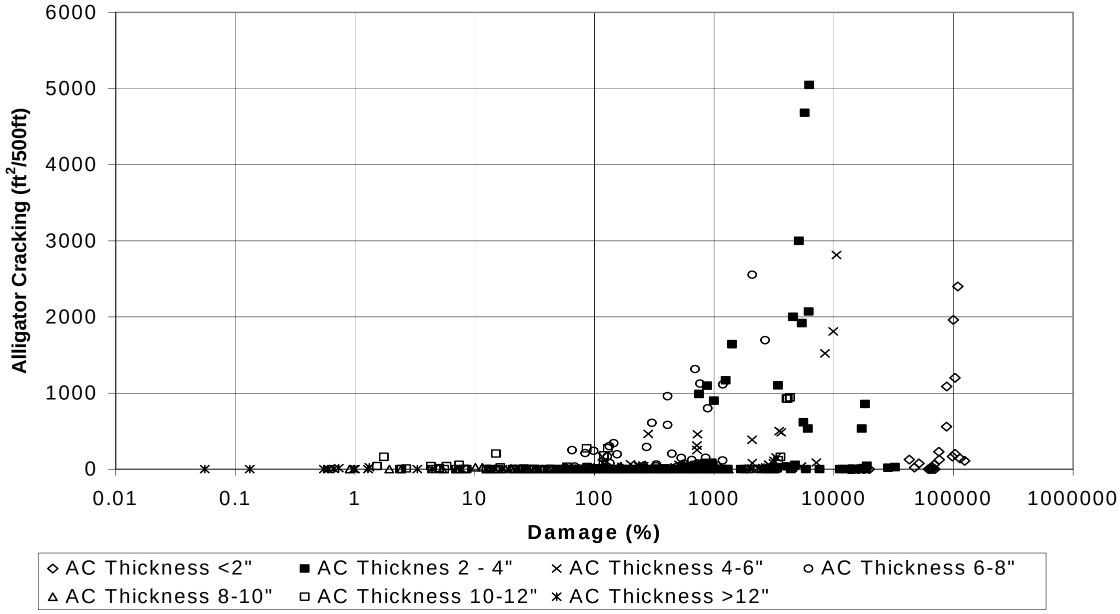

Figure C-9 Alligator Cracking vs. Predicted Bottom-Up Damage (AC 1,1.2,1.5)

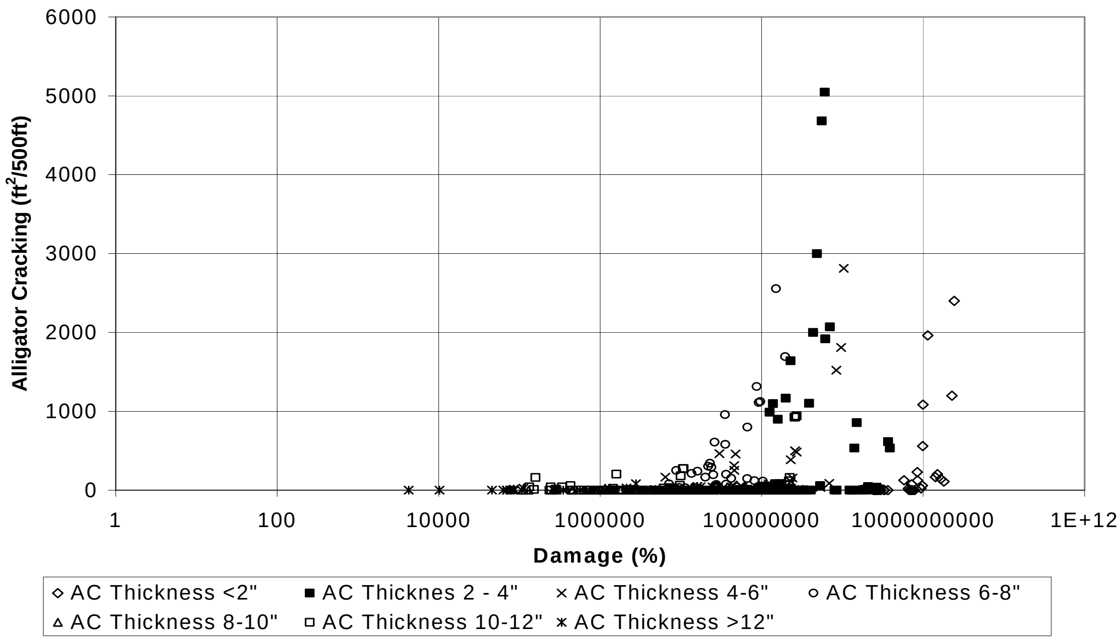

Figure C-10 Alligator Cracking vs. Predicted Bottom-Up Damage (AC 1,1.2,2.5)

Annex D

Top-Down Longitudinal Fatigue Cracking Shell Oil Model Calibration

Table D-1 Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using Shell Oil Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.9,0.9	0.9,1.0	0.9,1.1	1.0,0.9	1.0,1.0
11001	3.2	Sep-91	132	0	0	0	0	0.4687	3.14	21.34	0.00327	0.02128
11001	3.2	Apr-92	139	16	0	0	16	0.4827	3.246	22.14	0.00334	0.02179
11001	3.2	Jul-92	142	14	0	0	14	0.4955	3.327	22.66	0.00344	0.02239
11001	3.2	Jan-93	148	30	0	0	30	0.519	3.496	23.9	0.00358	0.0234
11019	6.7	May-89	32					0.1526	0.9351	5.771	0.001	0.00604
11019	6.7	Apr-90	43					0.2051	1.26	7.795	0.00133	0.00809
11019	6.7	Jan-91	52					0.248	1.523	9.417	0.00161	0.00977
11019	6.7	Jun-91	57	4	0	0	4	0.2729	1.676	10.36	0.00177	0.01074
11019	6.7	Mar-92	66					0.3144	1.936	12	0.00203	0.01235
11019	6.7	Mar-93	78	139	0	0	139	0.3711	2.287	14.19	0.00239	0.01456
11019	6.7	Jul-95	106	0	0	0	0	0.5047	3.112	19.31	0.00324	0.01977
11019	6.7	Jan-98	136	0	0	0	0	0.6437	3.981	24.78	0.00411	0.02515
14126	13.1	Jun-89	15	0	0	0	0	0.0016	0.0098	0.06034	1E-05	6.3E-05
14126	13.1	Mar-91	36	0	0	0	0	0.00396	0.02504	0.1599	2.5E-05	0.00015
14126	13.1	Mar-93	60	0	0	0	0	0.00572	0.03673	0.2383	3.4E-05	0.00022
14126	13.1	Apr-94	73	0	0	0	0	0.00679	0.04355	0.2816	4.1E-05	0.00026
14126	13.1	Dec-95	93	0	0	0	0	0.00816	0.05235	0.3385	4.9E-05	0.00031
14126	13.1	Dec-97	117	0	0	0	0	0.0099	0.06389	0.4161	5.8E-05	0.00037
21001	3	May-90	83	0	0	0	0	3.853	30.76	245.6	0.03875	0.3094
21001	3	Aug-91	98	0	0	0	0	3.877	30.95	247.1	0.03891	0.3107
21001	3	Aug-93	122	27	0	0	27	4.806	38.36	306.3	0.04823	0.3851
21001	3	Jun-95	144	0	0	0	0	5.721	45.67	364.6	0.05742	0.4584
21001	3	Aug-97	170	0	0	0	0	6.643	53.03	423.4	0.06667	0.5323
21001	3	Aug-98	182	0	0	0	0	7.547	60.25	481	0.07584	0.6055
21002	3.3	May-90	68	0	0	0	0	0.2927	2.416	19.95	0.00243	0.0201
21002	3.3	Aug-91	83	6	0	0	6	0.3407	2.813	23.22	0.00283	0.0234
21002	3.3	Aug-93	107	0	0	0	0	0.4368	3.606	29.78	0.00363	0.02999
21002	3.3	Jun-95	129	0	0	0	0	0.533	4.4	36.33	0.00443	0.0366
21002	3.3	Aug-97	155	0	0	0	0	0.6297	5.198	42.92	0.00524	0.04322
21002	3.3	May-98	164	0	0	0	0	0.6781	5.599	46.23	0.00564	0.04655
40113	4.5	Feb-95	19	0	0	0	0	1.319	7.593	44.65	0.01168	0.06457
40113	4.5	Mar-95	20	11	0	0	11	1.331	7.673	45.22	0.01172	0.0649
40113	4.5	Aug-95	25	0	0	0	0	1.974	11.29	65.69	0.0174	0.09637
40113	4.5	Nov-95	28	0	0	0	0	2.131	12.22	71.21	0.01855	0.103
40113	4.5	Feb-96	31	0	0	0	0	2.191	12.67	74.57	0.01879	0.1048
40113	4.5	Apr-96	33	0	0	0	0	2.237	12.96	76.48	0.01906	0.1065
40113	4.5	Jul-96	36	0	0	0	0	2.75	15.85	92.82	0.02353	0.1314
40113	4.5	Aug-96	37	0	0	0	0	2.986	17.18	100.4	0.0256	0.143
40113	4.5	Jan-98	54	53	17	0	70	4.525	26.54	158.4	0.03773	0.2137
40113	4.5	Apr-98	57	17	65	0	82	4.586	26.98	161.6	0.03799	0.2155
40113	4.5	Jun-98	59	24	59	0	83	4.856	28.51	170.4	0.04025	0.2283

Table D-1 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using Shell Oil Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{t2} and β_{t3})				
				Low	Medium	High	Total	0.9,0.9	0.9,1.0	0.9,1.1	1.0,0.9	1.0,1.0
40113	4.5	Oct-98	63	0	173	0	173	5.524	32.35	192.6	0.04574	0.2595
40114	6.8	Feb-95	19	0	0	0	0	0.5028	3.326	22.22	0.00276	0.0179
40114	6.8	Mar-95	20	31	0	0	31	0.518	3.433	22.97	0.00282	0.01839
40114	6.8	Aug-95	25	0	0	0	0	0.846	5.564	36.9	0.0047	0.03047
40114	6.8	Nov-95	28	0	0	0	0	0.9953	6.56	43.58	0.00551	0.03578
40114	6.8	Feb-96	31	7	0	0	7	1.007	6.644	44.21	0.00555	0.03608
40114	6.8	Apr-96	33	9	0	0	9	1.067	7.052	47	0.00585	0.03811
40114	6.8	Jul-96	36	44	0	0	44	1.326	8.736	57.99	0.00734	0.04768
40114	6.8	Aug-96	37	0	0	0	0	1.432	9.42	62.43	0.00795	0.05162
40114	6.8	Jan-98	54	33	40	26	98	2.104	13.91	92.65	0.01158	0.07545
40114	6.8	Apr-98	57	0	41	0	41	2.147	14.21	94.76	0.01178	0.07682
40114	6.8	Jun-98	59	0	42	0	42	2.311	15.28	101.8	0.01269	0.08274
40114	6.8	Oct-98	63	38	23	0	61	2.709	17.9	119.1	0.01491	0.09719
40115	15.1	Feb-95	19	0	0	0	0	0.00983	0.05843	0.3506	5.5E-05	0.00032
40115	15.1	Mar-95	20	33	0	0	33	0.00984	0.05846	0.3508	5.5E-05	0.00032
40115	15.1	Jan-98	54	0	0	0	0	0.02136	0.1298	0.7967	0.00011	0.00065
40116	16.2	Feb-95	19	0	0	0	0	0.01907	0.114	0.6868	0.00011	0.00066
40116	16.2	Mar-95	20	18	0	0	18	0.01909	0.1141	0.6876	0.00011	0.00066
40116	16.2	Jan-98	54	0	0	0	0	0.04171	0.2551	1.573	0.00022	0.00131
40117	11.8	Feb-95	19	0	0	0	0	0.01388	0.08951	0.5865	5.9E-05	0.00037
40117	11.8	Mar-95	20	14	0	0	14	0.01389	0.08957	0.5869	5.9E-05	0.00037
40117	11.8	Jan-98	54	0	0	0	0	0.04383	0.2843	1.866	0.00018	0.00113
40118	11.7	Feb-95	19	0	0	0	0	0.00259	0.01843	0.1346	8.5E-06	5.8E-05
40118	11.7	Mar-95	20	15	0	0	15	0.00259	0.01843	0.1346	8.5E-06	5.8E-05
40118	11.7	Jan-98	54	0	0	0	0	0.00699	0.04967	0.3612	2.2E-05	0.00015
41007	6.5	Sep-91	162	0	0	0	0	1.06	6.925	45.56	0.00608	0.03921
41007	6.5	Feb-93	163	57	0	0	57	1.074	7.017	46.17	0.00616	0.03974
41007	6.5	Sep-94	198	167	0	0	167	1.463	9.566	63	0.00837	0.05409
41024	10.8	Nov-89	149					1.826	11.15	68.48	0.00899	0.05423
41024	10.8	Aug-90	158					1.975	12.07	74.23	0.0097	0.05857
41024	10.8	Oct-92	184	0	0	0	0	2.487	15.24	93.9	0.01214	0.07351
41024	10.8	Mar-95	213	9	0	0	9	3.125	19.16	118.1	0.01528	0.0926
41024	10.8	Jul-95	217	23	0	0	23	3.268	20.04	123.6	0.01596	0.09678
41024	10.8	Aug-95	218	127	0	0	127	3.326	20.41	125.9	0.01623	0.09844
41024	10.8	Nov-95	221	109	0	0	109	3.365	20.65	127.4	0.0164	0.09947
41024	10.8	Feb-96	224	61	0	0	61	3.365	20.65	127.4	0.0164	0.09947
41024	10.8	Apr-96	226	79	0	23	102	3.376	20.72	127.9	0.01645	0.09977
41024	10.8	Jun-96	228	59	0	0	59	3.497	21.47	132.4	0.01704	0.1034
41024	10.8	Aug-96	230	59	0	0	59	3.719	22.82	140.8	0.01816	0.1102
41024	10.8	Apr-98	250	49	0	4	53	4.034	24.8	153.3	0.01959	0.119
41024	10.8	Jun-98	252	49	0	4	53	4.162	25.59	158.1	0.02021	0.1228
41024	10.8	Oct-98	256	50	0	4	54	4.439	27.3	168.8	0.02155	0.131
81029	4.2	Oct-91	233	0	25	0	25	0.2851	2.373	19.77	0.00204	0.01699
81029	4.2	Jul-94	266	44	0	0	44	0.3238	2.696	22.47	0.00229	0.0191

Table D-1 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using Shell Oil Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{t2} and β_{t3})				
				Low	Medium	High	Total	0.9,0.9	0.9,1.0	0.9,1.1	1.0,0.9	1.0,1.0
81029	4.2	Sep-95	280	11	0	0	11	0.3284	2.734	22.78	0.00232	0.0193
81053	4.6	Oct-89	60					2.285	18.29	146.4	0.02051	0.1642
81053	4.6	Jul-90	69					2.288	18.31	146.6	0.02052	0.1643
81053	4.6	Apr-93	102	92	0	0	92	4.028	32.24	258.1	0.03633	0.291
81053	4.6	Nov-93	109	18	0	0	18	4.068	32.56	260.6	0.03656	0.2928
81053	4.6	Dec-93	110	33	0	0	33	4.069	32.57	260.7	0.03657	0.2928
81053	4.6	Oct-94	120	108	0	0	108	4.078	32.64	261.3	0.03661	0.2932
81053	4.6	Feb-95	124	228	0	0	228	4.08	32.66	261.4	0.03662	0.2932
81053	4.6	May-95	127	229	0	0	229	4.081	32.66	261.4	0.03662	0.2932
81053	4.6	May-96	139	0	0	0	0	4.124	32.99	264	0.03689	0.2953
81053	4.6	Oct-96	144	0	0	0	0	4.843	38.36	304	0.04336	0.3436
81053	4.6	Nov-96	145	33	0	0	33	4.844	38.36	304.1	0.04336	0.3436
81053	4.6	Mar-97	149	45	0	0	45	4.844	38.37	304.1	0.04336	0.3436
91803	7.2	Jul-89	49					6.112	49.57	402.1	0.06723	0.5453
91803	7.2	Sep-90	63					6.97	56.53	458.5	0.07437	0.6032
91803	7.2	Aug-91	74	7	0	0	7	13.99	113.5	920.6	0.1554	1.26
91803	7.2	Sep-92	87	5	0	0	5	14.27	115.8	939	0.1576	1.278
91803	7.2	May-94	107	103	0	0	103	24.96	202.4	1642	0.2771	2.248
91803	7.2	May-95	119	207	7	0	214	25.34	205.5	1667	0.2801	2.272
91803	7.2	Oct-96	136	364	0	0	364	25.6	207.7	1684	0.2819	2.286
91803	7.2	May-97	143	557	0	0	557	26.92	218.3	1771	0.2923	2.371
91803	7.2	Sep-97	147	74	0	0	74	26.92	218.3	1771	0.2923	2.371
91803	7.2	Jun-98	156	279	11	0	290	40.73	330.4	2679	0.4517	3.664
120103	12	Dec-96	14	0	0	0	0	4.8E-05	0.00033	0.00222	1.4E-07	9.3E-07
120104	18	Dec-96	14	0	0	0	0	0.00033	0.00212	0.01374	1.4E-06	8.9E-06
120105	7.9	Dec-96	14	0	0	0	0	0.00387	0.02545	0.1681	1.7E-05	0.00011
120106	15	Dec-96	14	0	0	0	0	0.00025	0.00162	0.01034	1.1E-06	6.8E-06
123995	5	Apr-92	197	34	0	0	34	5.39	39.56	291.3	0.02211	0.1616
123995	5	Mar-94	220	82	0	0	82	6.065	44.56	328.5	0.02485	0.1819
123995	5	Jan-96	242	215	0	0	215	6.703	49.25	363.1	0.02745	0.201
123995	5	Jan-96	243	72	0	0	72	6.736	49.5	365.1	0.02758	0.202
123997	3.1	Aug-90	195					1.855	11.7	74.28	0.01558	0.09673
123997	3.1	Oct-91	209					2.077	13.11	83.21	0.01745	0.1084
123997	3.1	Mar-93	226					2.279	14.41	91.63	0.01906	0.1186
123997	3.1	Mar-94	238					2.459	15.56	99.02	0.02053	0.1278
124105	2.3	Apr-89	53	0	0	0	0	68.3	428.8	2706	0.7973	4.942
124105	2.3	Oct-91	83	0	0	0	0	115.9	729.5	4615	1.349	8.387
124105	2.3	Mar-93	100	0	0	0	0	135	851.9	5403	1.562	9.733
124106	8.2	Apr-89	21					0.0439	0.292	1.95	0.00017	0.00112
124106	8.2	Feb-91	43					0.1039	0.6965	4.688	0.0004	0.00264
124106	8.2	Jul-91	48	0	0	0	0	0.1195	0.8005	5.383	0.00046	0.00304
124106	8.2	Mar-94	80	10	0	0	10	0.2103	1.419	9.612	0.00079	0.00532
124106	8.2	Jan-97	114	50	0	0	50	0.3117	2.109	14.32	0.00117	0.00788
124107	2.7	Dec-89	75	0	0	0	0	1.006	6.532	42.56	0.00925	0.05946
124107	2.7	Feb-91	89	261	0	0	261	1.183	7.711	50.43	0.01075	0.06938

Table D-1 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using Shell Oil Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.9,0.9	0.9,1.0	0.9,1.1	1.0,0.9	1.0,1.0
124107	2.7	Jul-91	94	343	0	0	343	1.283	8.363	54.67	0.01168	0.07536
124107	2.7	Mar-93	114	18	0	0	18	1.61	10.52	68.9	0.01457	0.09419
124107	2.7	Mar-94	126	37	13	0	51	1.808	11.83	77.66	0.01627	0.1054
124107	2.7	Jan-96	148	67	0	0	67	2.239	14.67	96.44	0.02007	0.1302
124107	2.7	Mar-97	162	0	0	0	0	2.503	16.42	108.1	0.02235	0.1451
124108	9.9	Apr-89	35	0	0	0	0	0.00389	0.02491	0.1619	2.4E-05	0.00015
124108	9.9	Jan-91	56	0	0	0	0	0.00494	0.03164	0.205	2.9E-05	0.00018
124108	9.9	Oct-91	65	0	0	0	0	0.00706	0.04675	0.3134	4.1E-05	0.00026
124108	9.9	Mar-94	94	7	0	0	7	0.00824	0.0544	0.3635	4.6E-05	0.0003
124108	9.9	Aug-94	99	0	0	0	0	0.01048	0.07062	0.4812	5.8E-05	0.00039
124108	9.9	Jan-96	116	0	0	0	0	0.01116	0.07508	0.5108	6.1E-05	0.00041
124135	1.4	Dec-89	227	99	199	0	298	13450	91930	635300	227.1	1538
124135	1.4	Jan-91	240	412	271	0	683	13970	95340	658100	235.3	1592
131031	11.1	Apr-91	119					0.00681	0.05514	0.4469	3E-05	0.00024
131031	11.1	Jul-92	134					0.00688	0.05562	0.4503	3E-05	0.00024
131031	11.1	Jan-93	140					0.00981	0.07945	0.6442	4.3E-05	0.00035
131031	11.1	Apr-94	155					0.01198	0.09702	0.7868	5.2E-05	0.00043
131031	11.1	Oct-94	161					0.01203	0.09739	0.7892	5.3E-05	0.00043
131031	11.1	Aug-95	171					0.01209	0.09776	0.7919	5.3E-05	0.00043
131031	11.1	Jan-96	176					0.01631	0.1321	1.072	7.2E-05	0.00058
131031	11.1	Apr-96	179					0.01631	0.1321	1.072	7.2E-05	0.00058
134111	8.7	Mar-89	101	27	0	0	27	0.01282	0.1038	0.8428	5.2E-05	0.00042
134111	8.7	Mar-91	125	291	0	0	291	0.022	0.1786	1.453	8.7E-05	0.00071
134111	8.7	Feb-92	136	477	0	0	477	0.02222	0.1799	1.461	8.8E-05	0.00071
134112	15.9	May-89	144	0	0	0	0	0.02868	0.1692	1.003	0.00027	0.00154
134112	15.9	Feb-91	165	17	0	0	17	0.03227	0.1914	1.14	0.00029	0.0017
134112	15.9	Apr-91	167	0	0	0	0	0.03228	0.1915	1.141	0.00029	0.0017
134112	15.9	Feb-94	201	0	0	0	0	0.04852	0.2885	1.723	0.00044	0.00257
134112	15.9	Oct-94	209	0	0	0	0	0.05106	0.3043	1.821	0.00046	0.00269
134112	15.9	Jan-96	224	0	0	0	0	0.05353	0.3195	1.915	0.00048	0.0028
134112	15.9	Feb-97	237	0	0	0	0	0.06179	0.3687	2.209	0.00055	0.00325
134112	15.9	Apr-98	251	0	0	0	0	0.06446	0.3853	2.312	0.00057	0.00337
134113	15.2	May-89	144	0	0	0	0	0.08602	0.4907	2.811	0.00088	0.00497
134113	15.2	Feb-91	165	0	0	0	0	0.09493	0.544	3.13	0.00096	0.0054
134113	15.2	Apr-91	167	0	0	0	0	0.09496	0.5442	3.132	0.00096	0.0054
134113	15.2	Feb-94	201	0	0	0	0	0.1389	0.7989	4.61	0.0014	0.00795
134113	15.2	Oct-94	209	0	0	0	0	0.1456	0.8387	4.849	0.00146	0.00828
134113	15.2	Jan-96	224	0	0	0	0	0.1519	0.8761	5.073	0.00151	0.0086
134113	15.2	Feb-97	237	31	0	0	31	0.1735	1.001	5.798	0.00173	0.00987
134113	15.2	Apr-98	251	37	0	0	37	0.1809	1.045	6.059	0.0018	0.01024
161001	3.7	Jul-89	192	155	0	0	155	3.553	29.76	249.8	0.02209	0.1854
161001	3.7	Aug-90	205	193	0	0	193	3.836	32.12	269.5	0.0237	0.1989
161001	3.7	Jun-93	239	78	0	0	78	4.827	40.44	339.4	0.02955	0.248
161001	3.7	Aug-94	253	199	0	0	199	5.092	42.63	357.6	0.03091	0.2593

Table D-1 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using Shell Oil Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.9,0.9	0.9,1.0	0.9,1.1	1.0,0.9	1.0,1.0
161001	3.7	May-95	262	183	2	0	185	5.843	48.99	411.5	0.03576	0.3003
161001	3.7	Jul-97	288	67	63	44	175	6.275	52.55	441	0.03788	0.3179
161001	3.7	Sep-98	302	0	159	5	164	7.16	60	503.7	0.0435	0.3653
161009	10.4	Sep-89	180					1.32	10.43	82.44	0.01175	0.09283
161009	10.4	Jul-90	190					1.599	12.63	99.84	0.01401	0.1108
161009	10.4	Jul-92	214	0	0	0	0	1.651	13.04	103.1	0.01435	0.1134
161009	10.4	Oct-93	229	8	0	0	8	1.994	15.75	124.5	0.01715	0.1355
161009	10.4	Jun-96	261	1	0	0	1	2.109	16.67	131.7	0.01787	0.1413
161009	10.4	Jul-97	274	0	0	0	0	2.549	20.14	159.2	0.02145	0.1695
161021	5.9	Sep-89	48					0.06179	0.4932	3.939	0.00046	0.0037
161021	5.9	Oct-90	61	0	0	0	0	0.06304	0.5027	4.013	0.00047	0.00374
161021	5.9	Aug-91	71	0	0	0	0	0.1229	0.982	7.848	0.00093	0.00743
161021	5.9	Aug-93	95	0	0	0	0	0.1252	0.9993	7.983	0.00094	0.0075
161021	5.9	Sep-95	120	0	0	0	0	0.1886	1.506	12.04	0.00142	0.01137
161021	5.9	Jun-96	129	5	0	0	5	0.1893	1.512	12.08	0.00143	0.01139
161021	5.9	Jul-97	142	0	0	0	0	0.1907	1.523	12.17	0.00143	0.01144
169034	9.2	Jul-89	10					0.00216	0.01664	0.1293	8.1E-06	6.2E-05
169034	9.2	Aug-90	23					0.03494	0.2771	2.202	0.00019	0.00154
169034	9.2	Jun-93	57	12	0	0	12	0.2764	2.206	17.61	0.00183	0.01457
169034	9.2	Aug-94	71	146	0	0	146	0.4801	3.833	30.6	0.00324	0.02588
169034	9.2	May-95	80					0.4821	3.848	30.73	0.00325	0.02594
169034	9.2	Jul-97	106	217	0	0	217	0.7135	5.696	45.48	0.00482	0.03846
169034	9.2	Sep-98	120	156	52	18	226	0.7162	5.716	45.63	0.00483	0.03853
201009	11.1	Aug-88	44	0	0	0	0	23	190.6	1580	0.2424	2.009
201009	11.1	May-89	53	11	0	0	11	23.27	192.8	1598	0.2441	2.023
201009	11.1	Dec-90	72	210	5	0	215	41.29	342.2	2836	0.4415	3.659
201009	11.1	Oct-91	82	6	1	0	7	45.08	373.5	3096	0.4778	3.959
201009	11.1	Apr-93	100	9	0	0	9	60.91	504.7	4183	0.6528	5.41
201009	11.1	Apr-95	124	16	28	0	43	72.59	601.6	4985	0.767	6.356
201009	11.1	Apr-96	136	0	0	0	0	73.18	606.5	5026	0.7716	6.394
201009	11.1	Jan-99	168	0	0	0	0	85.64	709.7	5881	0.887	7.35
251003	6.6	Aug-89	180	758	0	0	758	1.99	15.88	126.7	0.02022	0.1613
251003	6.6	Sep-90	193	691	0	0	691	2.401	19.16	152.9	0.02425	0.1935
251003	6.6	Aug-91	204	556	1	0	557	2.418	19.29	153.9	0.02435	0.1944
251003	6.6	Sep-92	217	600	0	0	600	2.469	19.69	157.1	0.02474	0.1974
251003	6.6	Oct-95	254	563	0	0	563	2.951	23.54	187.8	0.02936	0.2343
251003	6.6	Oct-96	266	39	0	0	39	3.008	23.99	191.4	0.02978	0.2377
251003	6.6	Jun-98	286	32	9	0	41	3.514	28.03	223.6	0.0347	0.2769
251004	9.6	Aug-89	178	0	0	0	0	0.5757	4.496	35.13	0.00446	0.03485
251004	9.6	Sep-90	191	19	0	0	19	0.6286	4.909	38.36	0.00483	0.03771
251004	9.6	Aug-91	202	16	0	0	16	0.7356	5.746	44.9	0.00566	0.04419
251004	9.6	Sep-92	215	0	0	0	0	0.738	5.763	45.02	0.00567	0.04428
251004	9.6	Oct-95	252	0	0	0	0	1.071	8.362	65.35	0.00819	0.06399
251004	9.6	Jun-97	272	3	0	0	3	1.152	8.998	70.31	0.00875	0.06836

Table D-1 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using Shell Oil Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.9,0.9	0.9,1.0	0.9,1.1	1.0,0.9	1.0,1.0
251004	9.6	Jun-98	284	3	0	0	3	1.32	10.31	80.56	0.01005	0.0785
261001	2.2	Jul-88	203	0	0	0	0	0.353	2.594	19.3	0.00316	0.02274
261001	2.2	Sep-89	217	16	0	0	16	0.3826	2.812	20.93	0.00343	0.02467
261001	2.2	Jul-90	227	24	0	0	24	0.4014	2.958	22.08	0.00359	0.02586
261001	2.2	Jul-91	239	0	0	0	0	0.4151	3.052	22.73	0.00372	0.02675
261001	2.2	Sep-91	241	51	0	0	51	0.4188	3.078	22.91	0.00376	0.027
261001	2.2	Sep-92	253	0	0	0	0	0.4291	3.15	23.41	0.00385	0.02765
261001	2.2	Jun-93	262	23	0	0	23	0.4476	3.294	24.54	0.00401	0.02884
261001	2.2	Jun-93	263	0	0	0	0	0.4509	3.316	24.69	0.00404	0.02906
261001	2.2	May-95	285	9	0	0	9	0.477	3.503	26.05	0.00427	0.0307
261001	2.2	Jul-96	299	5	0	0	5	0.5069	3.725	27.71	0.00454	0.03266
261004	4.2	Sep-89	51	321	0	0	321	8.079	62.5	483.6	0.09094	0.7037
261004	4.2	Jul-90	61	451	0	0	451	12.6	97.52	754.6	0.1455	1.126
271018	4.4	Apr-89	124	0	0	0	0	37.06	306.1	2528	0.3566	2.946
271018	4.4	Jun-89	126					37.06	306.1	2529	0.3566	2.946
271018	4.4	Oct-90	142					38.14	315	2602	0.3653	3.018
271018	4.4	Jun-93	174	41	1	0	41	51.2	422.8	3492	0.4944	4.084
271018	4.4	Jul-93	176	7	51	0	57	51.2	422.9	3493	0.4945	4.085
271018	4.4	Mar-94	183	58	39	0	98	57.19	472.3	3901	0.5553	4.588
271018	4.4	Aug-94	188	131	0	0	131	57.21	472.5	3902	0.5554	4.588
271087	15.7	Oct-91	154	0	0	0	0	25.55	204	1629	0.2529	2.02
271087	15.7	May-93	173	8	0	0	8	28.97	231.4	1848	0.2859	2.283
271087	15.7	Oct-94	190	24	0	0	24	30.38	242.6	1938	0.2997	2.393
271087	15.7	Jun-96	210	25	0	0	25	34.69	277	2212	0.3425	2.735
291008	11.4	Feb-92	70	0	0	0	0	0.9255	7.347	58.33	0.00635	0.05038
291008	11.4	Mar-93	83	58	3	0	61	0.9255	7.347	58.33	0.00635	0.05038
291008	11.4	Mar-93	83	28	34	0	62	26.16	164.2	1035	0.1803	1.122
291008	11.4	Apr-96	120	130	0	0	130	1.467	11.65	92.45	0.01001	0.07945
291008	11.4	Feb-00	152	26	0	0	26	1.956	15.53	123.3	0.0131	0.104
307088	4.9	Sep-89	100	0	0	0	0	0.534	4.294	34.6	0.00405	0.03263
307088	4.9	May-91	120	4	12	0	16	0.5828	4.69	37.81	0.00437	0.03524
308129	3.2	Oct-89	17					0.2095	1.643	12.91	0.00182	0.01429
308129	3.2	Jul-91	38					0.4154	3.259	25.61	0.00358	0.02812
308129	3.2	Jul-92	50	0	0	0	0	0.6288	4.936	38.81	0.00542	0.04253
308129	3.2	Aug-93	63	0	0	0	0	0.9342	7.337	57.71	0.00816	0.0641
308129	3.2	Dec-93	67	0	0	0	0	0.935	7.344	57.76	0.00816	0.06412
308129	3.2	Mar-94	70	0	0	0	0	0.9389	7.375	58.01	0.00818	0.06428
308129	3.2	Oct-94	77	0	0	0	0	0.946	7.422	58.33	0.00823	0.06461
308129	3.2	Feb-95	81	0	0	0	0	1.177	9.244	72.72	0.01023	0.08041
308129	3.2	May-95	84	0	0	0	0	1.186	9.315	73.28	0.01029	0.08084
308129	3.2	Jun-96	97	0	0	0	0	1.533	12.04	94.77	0.0134	0.1053
308129	3.2	Oct-96	101	0	0	0	0	1.537	12.07	94.92	0.01344	0.1056
308129	3.2	Jan-97	104	0	0	0	0	1.54	12.1	95.14	0.01346	0.1057
308129	3.2	Mar-97	106	0	0	0	0	1.542	12.11	95.24	0.01346	0.1057

Table D-1 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using Shell Oil Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.9,0.9	0.9,1.0	0.9,1.1	1.0,0.9	1.0,1.0
308129	3.2	Aug-97	111	0	0	0	0	1.549	12.16	95.57	0.01352	0.1061
308129	3.2	Oct-97	113	0	0	0	0	1.55	12.16	95.6	0.01352	0.1061
321020	7	Jul-91	86	34	0	0	34	6.581	54.74	455.3	0.06323	0.526
321020	7	Aug-93	111	138	0	0	138	10.68	88.82	738.8	0.1039	0.864
321020	7	Sep-94	123	29	20	0	49	11.04	91.85	764	0.1065	0.8857
321020	7	Apr-95	131	242	0	0	242	11.28	93.78	780.1	0.1079	0.898
321020	7	Jun-97	157	9	0	0	9	14.19	118	981.8	0.1332	1.108
321020	7	Jun-98	169	0	0	0	0	14.46	120.3	1000	0.1349	1.122
341031	7.3	Apr-92	224	333	1	0	333	7.638	59.57	466	0.06787	0.5304
341031	7.3	Feb-93	234	322	31	3	356	7.721	60.11	469.7	0.06849	0.5344
341031	7.3	Oct-95	266	0	352	170	522	8.155	63.16	491.3	0.0715	0.5553
341031	7.3	Nov-95	267	232	30	0	261	10.54	82.13	641.9	0.09229	0.7203
341033	7.4	Apr-92	211	52	2	0	54	0.1531	1.233	9.937	0.00113	0.00908
341033	7.4	Feb-93	221	32	11	0	44	0.1579	1.272	10.25	0.00116	0.00931
341033	7.4	Nov-95	254	55	0	0	55	0.1985	1.599	12.89	0.00146	0.01173
341033	7.4	Jul-97	274	260	0	0	260	0.2036	1.64	13.22	0.00149	0.01198
341034	11.1	Oct-89	48	0	0	0	0	3.808	30.53	244.7	0.03281	0.263
341034	11.1	Sep-90	59	0	0	0	0	3.81	30.54	244.8	0.03282	0.2631
341034	11.1	Apr-92	78	0	0	0	0	6.113	49	392.8	0.05179	0.4152
341034	11.1	Feb-93	88	0	0	0	0	6.115	49.02	393	0.0518	0.4152
341034	11.1	Nov-95	121	3	0	0	3	8.824	70.73	567	0.07411	0.5941
341034	11.1	Jul-97	141	0	15	0	15	11.62	93.15	746.8	0.09732	0.7802
350101	7.2	May-97	19	0	0	0	0	0.4642	3.491	26.68	0.00261	0.01935
350102	4.8	May-97	19	0	0	0	0	1.322	10.13	78.43	0.00777	0.05922
350103	12.5	May-97	19	0	0	0	0	0.05354	0.4397	3.611	0.00022	0.00185
350104	19.2	May-97	19	0	0	0	0	0.00022	0.0013	0.00762	1.1E-06	6.6E-06
350105	9.9	May-97	19	0	0	0	0	0.08719	0.7126	5.834	0.00038	0.00313
350106	15.6	May-97	19	0	0	0	0	0.03823	0.3054	2.44	0.00016	0.0013
351005	8.9	Oct-89	73	0	0	0	0	0.1388	1.109	8.912	0.00081	0.00644
351005	8.9	Mar-91	90	0	0	0	0	0.2307	1.853	14.97	0.00136	0.01089
351005	8.9	Oct-92	109	0	0	0	0	0.2498	1.994	16.02	0.00145	0.01159
351005	8.9	Feb-94	125	0	0	0	0	0.2785	2.217	17.77	0.0016	0.01272
351005	8.9	Mar-95	138	0	0	0	0	0.4027	3.228	26.02	0.00234	0.01871
351005	8.9	Apr-97	163	0	0	0	0	0.4518	3.6	28.88	0.00258	0.02056
351022	6.3	Oct-89	37	0	0	0	0	0.2029	1.625	13.06	0.00139	0.01116
351022	6.3	Mar-91	54	0	0	0	0	0.5071	4.101	33.23	0.00351	0.02844
351022	6.3	Oct-92	73	0	0	0	0	0.5259	4.231	34.15	0.00361	0.0291
351022	6.3	Feb-94	89	0	0	0	0	0.9359	7.569	61.34	0.00645	0.05226
351022	6.3	Mar-95	102	0	0	0	0	0.9492	7.664	62.03	0.00652	0.05272
351022	6.3	Apr-97	127	0	0	0	0	1.818	14.74	119.6	0.01274	0.1035
351112	6.3	Dec-89	67					0.2074	1.456	10.33	0.00105	0.00729
351112	6.3	Jan-91	80					0.2468	1.739	12.37	0.00125	0.00866
351112	6.3	Mar-91	82	0	0	0	0	0.2486	1.753	12.47	0.00126	0.00872
351112	6.3	Jan-93	104	0	0	0	0	0.3237	2.279	16.2	0.00164	0.01136
351112	6.3	Feb-94	117	0	0	0	0	0.3632	2.562	18.25	0.00183	0.01274

Table D-1 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using Shell Oil Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.9,0.9	0.9,1.0	0.9,1.1	1.0,0.9	1.0,1.0
351112	6.3	Oct-94	125	0	0	0	0	0.3961	2.791	19.85	0.002	0.0139
351112	6.3	Mar-95	130	14	0	0	14	0.4055	2.865	20.44	0.00204	0.01421
351112	6.3	Apr-95	131	0	0	0	0	0.4077	2.881	20.55	0.00205	0.01428
351112	6.3	Jun-95	133	0	0	0	0	0.4172	2.947	21.01	0.0021	0.01462
351112	6.3	Nov-96	150	0	0	0	0	0.4761	3.36	23.93	0.0024	0.01669
351112	6.3	Apr-97	155	0	0	0	0	0.4837	3.416	24.35	0.00243	0.01694
351112	6.3	Sep-97	160	0	0	0	0	0.5093	3.592	25.56	0.00257	0.01786
371024	4.8	Nov-89	109					0.07175	0.5805	4.706	0.00052	0.00424
371024	4.8	Mar-91	125					0.1187	0.9638	7.836	0.00088	0.00712
371024	4.8	Apr-92	138	3	0	0	3	0.1208	0.9804	7.966	0.00089	0.00722
371802	4.5	Mar-91	66					0.2424	1.602	10.66	0.00219	0.01428
371802	4.5	Oct-92	85	28	0	0	28	0.3207	2.118	14.08	0.0029	0.0189
371802	4.5	Apr-94	103	0	0	0	0	0.3708	2.452	16.32	0.00334	0.02179
371802	4.5	Jul-95	118	41	0	0	41	0.4288	2.834	18.86	0.00386	0.0252
371802	4.5	Apr-96	127	0	0	0	0	0.455	3.011	20.07	0.00409	0.02671
371992	2.4	Mar-91	14					0.1729	1.14	7.585	0.00152	0.00981
371992	2.4	Oct-92	33	22	0	0	22	0.5399	3.508	23.01	0.00491	0.03124
371992	2.4	Apr-94	51	0	0	0	0	0.8752	5.959	41.11	0.00747	0.04963
371992	2.4	Feb-96	73	0	0	0	0	1.513	10.44	73	0.01283	0.08651
404087	10.1	Jan-90	43	0	0	0	0	0.00086	0.00635	0.04757	4.1E-06	0.00003
404087	10.1	Oct-91	64	0	0	0	0	0.0019	0.01424	0.1078	9E-06	6.6E-05
404087	10.1	Nov-92	77	31	0	0	31	0.00194	0.01447	0.1092	9.2E-06	6.7E-05
404087	10.1	Feb-93	80	35	0	0	35	0.00194	0.01447	0.1092	9.2E-06	6.7E-05
404087	10.1	Nov-94	101	143	0	0	143	0.00322	0.02423	0.1839	1.5E-05	0.00011
404087	10.1	Feb-95	104	112	0	0	112	0.00322	0.02423	0.1839	1.5E-05	0.00011
404087	10.1	Aug-95	110	0	159	0	159	0.00326	0.02447	0.1853	1.5E-05	0.00011
404087	10.1	Jun-97	132	10	0	0	10	0.00337	0.02511	0.1892	1.6E-05	0.00012
404163	11.5	Jan-90	34					0.3714	3.051	25.06	0.00228	0.01876
404163	11.5	Mar-91	48					0.3793	3.115	25.59	0.00232	0.01904
404163	11.5	Oct-91	55	0	0	0	0	0.3795	3.116	25.59	0.00232	0.01904
404163	11.5	Nov-92	68	0	0	0	0	0.7879	6.471	53.15	0.00486	0.03994
404163	11.5	Mar-93	72	7	0	0	7	0.7886	6.477	53.2	0.00487	0.03996
404163	11.5	Nov-94	92	0	0	0	0	0.7967	6.543	53.74	0.0049	0.04025
404163	11.5	Apr-96	109	0	0	0	0	1.211	9.946	81.7	0.00748	0.06144
404163	11.5	Aug-97	125	45	8	0	53	1.211	9.947	81.7	0.00748	0.06144
404163	11.5	Jan-99	141	6	9	0	15	1.609	13.22	108.6	0.00993	0.08158
404165	8.1	Jan-90	68					6.172	51.05	422.3	0.04231	0.35
404165	8.1	Mar-91	82					6.507	53.81	445.1	0.04426	0.3661
404165	8.1	Oct-91	89	4	0	0	4	6.513	53.85	445.4	0.04428	0.3663
404165	8.1	Nov-92	102	5	0	0	5	9.721	80.4	665.1	0.06666	0.5515
404165	8.1	Mar-93	106	19	0	0	19	9.732	80.49	665.9	0.06671	0.5519
404165	8.1	Oct-94	125	9	0	0	9	10.09	83.45	690.3	0.06879	0.5691
404165	8.1	Nov-94	126	16	0	0	16	10.09	83.48	690.5	0.06881	0.5692
404165	8.1	Apr-95	131	24	0	0	24	10.45	86.4	714.7	0.07087	0.5863

Table D-1 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using Shell Oil Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.9,0.9	0.9,1.0	0.9,1.1	1.0,0.9	1.0,1.0
404165	8.1	Jun-95	133	25	0	0	25	10.45	86.41	714.7	0.07088	0.5863
404165	8.1	Apr-96	143	25	0	0	25	13.88	114.8	950	0.09483	0.7846
404165	8.1	Nov-96	150	60	0	0	60	13.89	114.9	950.2	0.09486	0.7848
404165	8.1	May-97	156	26	0	0	26	13.9	115	951.1	0.09491	0.7852
404165	8.1	Sep-97	160	24	0	0	24	13.91	115	951.3	0.09493	0.7853
421599	12.3	Aug-89	25					11.92	97.97	805.4	0.1252	1.029
421599	12.3	Sep-90	38					19.32	158.8	1306	0.2061	1.695
421599	12.3	Mar-93	68	0	0	0	0	42.25	347.3	2855	0.4507	3.705
421599	12.3	Sep-94	86	0	0	0	0	42.71	351.1	2886	0.4539	3.731
421599	12.3	Jun-95	95	8	0	0	8	59.15	486.3	3997	0.6282	5.164
421599	12.3	Jul-96	108	4	0	0	4	69.65	572.5	4707	0.743	6.108
421599	12.3	Mar-98	128	2	0	0	2	70.77	581.7	4782	0.7508	6.172
451011	3.2	Mar-92	69	0	0	0	0	1.043	6.627	42.44	0.00809	0.05027
451011	3.2	Oct-92	76	0	0	0	0	1.235	7.82	49.92	0.00964	0.05986
451011	3.2	Jun-93	84	0	0	0	0	1.301	8.262	52.91	0.01007	0.06266
451011	3.2	Jan-96	115	16	0	0	16	1.755	11.18	71.8	0.01353	0.0844
451011	3.2	Jun-97	132	0	0	0	0	1.984	12.66	81.42	0.01522	0.09512
451011	3.2	Feb-99	150	0	0	0	0	2.296	14.65	94.22	0.01765	0.1103
473104	1.3	Aug-89	39					2.953	18.99	123	0.06208	0.3923
473104	1.3	Nov-89	42					2.988	19.24	124.8	0.06252	0.3954
473104	1.3	May-91	60					3.181	20.62	134.8	0.0649	0.4123
473104	1.3	Aug-91	63					3.216	20.85	136.3	0.06538	0.4154
473104	1.3	Oct-92	77					3.418	22.27	146.4	0.06798	0.4336
473104	1.3	Aug-93	87					3.559	23.29	153.7	0.06976	0.4461
473104	1.3	Nov-95	114					4.126	27.32	182.5	0.07729	0.499
473104	1.3	Oct-96	125					4.354	28.92	194	0.08027	0.5198
480001	2.4	Apr-89	1					0.2568	1.481	8.594	0.00344	0.01955
480001	2.4	Oct-90	19					9.736	55.7	320.6	0.1383	0.7795
480001	2.4	May-91	26	0	0	0	0	11.03	63.7	370.4	0.153	0.8687
480001	2.4	Feb-93	47	0	0	0	0	22.91	133	777.7	0.3149	1.799
480001	2.4	Apr-93	49	0	0	0	0	23.53	136.8	801	0.322	1.842
480001	2.4	Feb-95	71	0	0	0	0	37.23	218.2	1287	0.5002	2.886
480001	2.4	Mar-95	72	0	0	0	0	37.46	219.7	1296	0.5026	2.901
480001	2.4	May-97	98	34	0	0	34	54.66	322.7	1917	0.7203	4.187
480001	2.4	Mar-98	108	34	0	0	34	63.33	374.2	2224	0.8338	4.851
481060	7.5	Jun-90	52	0	0	0	0	10.25	65.28	417.7	0.05783	0.3644
481060	7.5	Feb-91	60	0	0	0	0	12.38	78.93	505.7	0.06967	0.4396
481060	7.5	Apr-91	62	0	0	0	0	12.73	81.26	521.4	0.07133	0.4506
481060	7.5	Mar-92	73	12	0	0	12	16.06	102.6	658.4	0.08994	0.5686
481060	7.5	Feb-93	84	19	0	0	19	19.51	124.8	801.8	0.1091	0.6904
481060	7.5	Mar-93	85	23	0	0	23	19.6	125.4	806	0.1095	0.6931
481060	7.5	Oct-94	104	14	0	0	14	27.79	178	1146	0.1548	0.9821
481060	7.5	Feb-95	108	28	0	0	28	28.04	179.8	1158	0.1559	0.9897
481060	7.5	Mar-95	109	0	0	0	0	28.15	180.5	1163	0.1564	0.9929

Table D-1 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using Shell Oil Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.9,0.9	0.9,1.0	0.9,1.1	1.0,0.9	1.0,1.0
481060	7.5	Mar-95	112	14	0	0	14	29.46	189	1219	0.1634	1.038
481060	7.5	Jun-95	134	8	0	0	8	37.8	242.9	1568	0.209	1.33
481060	7.5	Apr-97	137	31	0	0	31	40.02	257.1	1659	0.2216	1.409
481060	7.5	Jul-97	139	31	2	0	33	41.77	268.2	1730	0.2316	1.473
481060	7.5	Sep-97	154	32	0	0	32	47.93	308.2	1991	0.2648	1.686
481077	5.1	Apr-89	88					1.715	13.22	102.1	0.01095	0.08462
481077	5.1	Nov-91	119	0	0	0	0	2.55	19.67	151.9	0.01632	0.1261
481077	5.1	Oct-92	130	28	0	0	28	2.82	21.75	167.9	0.01794	0.1387
481077	5.1	May-93	137	124	0	0	124	2.841	21.91	169.1	0.01802	0.1393
481077	5.1	Oct-94	154	143	0	0	143	2.883	22.21	171.3	0.01819	0.1405
481077	5.1	Mar-95	159	47	0	0	47	3.603	27.8	214.7	0.02279	0.1762
481077	5.1	Apr-95	160	181	0	0	181	3.605	27.81	214.8	0.02279	0.1762
481077	5.1	Jun-95	162	181	0	0	181	3.609	27.84	215	0.02281	0.1763
481077	5.1	Aug-95	164	181	0	0	181	3.613	27.86	215.1	0.02283	0.1764
481077	5.1	Jun-96	174	181	0	0	181	3.643	28.09	216.8	0.02294	0.1773
481077	5.1	May-97	185	228	10	0	238	3.675	28.33	218.5	0.02307	0.1782
481077	5.1	Jul-97	187	300	0	0	300	3.679	28.35	218.7	0.02309	0.1783
481077	5.1	Sep-97	189	276	0	0	276	3.683	28.37	218.9	0.0231	0.1784
481077	5.1	Mar-98	195	281	0	0	281	4.482	34.58	267	0.02822	0.2182
481109	6.5	Jan-90	68					2.502	14.02	79.3	0.02236	0.1234
481109	6.5	Sep-90	76					2.836	15.91	89.94	0.02522	0.1394
481109	6.5	May-91	84	123	0	0	123	3.21	18.13	103.2	0.02826	0.1573
481109	6.5	Feb-93	105	148	0	0	148	4.217	23.98	137.4	0.03657	0.2054
481109	6.5	Jul-93	110	336	0	0	336	4.456	25.32	144.9	0.03861	0.2168
481109	6.5	Feb-95	129	502	3	0	505	5.477	31.32	180.3	0.04696	0.2656
481109	6.5	May-95	132	571	0	0	571	5.642	32.26	185.7	0.04835	0.2735
481109	6.5	Aug-96	147	425	0	0	425	6.485	37.13	213.9	0.05533	0.3136
481169	1.1	Feb-90	211					319.3	1954	12050	4.287	26.09
481169	1.1	Mar-90	212					321.2	1966	12120	4.313	26.25
481169	1.1	Sep-90	218					327.6	2001	12320	4.404	26.75
481169	1.1	Jan-91	222	0	0	0	0	338.5	2072	12780	4.545	27.66
481169	1.1	Mar-91	224					343.1	2100	12950	4.605	28.03
481169	1.1	Jun-91	227	0	0	0	0	346.4	2119	13060	4.653	28.3
481169	1.1	Jan-92	234					360.7	2208	13620	4.841	29.47
481169	1.1	Feb-93	247	0	0	0	0	385.7	2363	14580	5.175	31.52
481169	1.1	Aug-93	253	0	0	0	0	392.9	2404	14820	5.277	32.1
481169	1.1	Mar-95	272	7	0	0	7	432.9	2653	16380	5.807	35.38
481169	1.1	Jul-95	276	0	0	0	0	437.5	2678	16520	5.872	35.74
481169	1.1	Jul-97	300	0	0	0	0	484.4	2967	18310	6.499	39.58
481174	4.7	Oct-90	186					0.1774	1.196	8.113	0.00091	0.00609
481174	4.7	Feb-91	190					0.1792	1.21	8.21	0.00092	0.00615
481174	4.7	Apr-91	192	201	0	0	201	0.1809	1.221	8.292	0.00093	0.00621
481174	4.7	Mar-92	203	204	0	0	204	0.1912	1.292	8.773	0.00098	0.00656
481174	4.7	Feb-93	214	138	0	0	138	0.2014	1.36	9.237	0.00103	0.00691

Table D-1 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using Shell Oil Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.9,0.9	0.9,1.0	0.9,1.1	1.0,0.9	1.0,1.0
481174	4.7	Mar-93	215	185	0	0	185	0.2021	1.366	9.275	0.00104	0.00694
481174	4.7	Feb-95	238	220	10	0	229	0.2233	1.509	10.26	0.00115	0.00766
481174	4.7	Mar-95	239	179	0	0	179	0.2241	1.514	10.29	0.00115	0.00768
481174	4.7	Jan-96	249	160	0	0	160	0.2333	1.577	10.71	0.0012	0.008
481174	4.7	Apr-97	264	0	0	0	0	0.2467	1.668	11.34	0.00126	0.00846
481174	4.7	Mar-98	275	49	0	0	49	0.2564	1.734	11.79	0.00131	0.00879
481178	8.5	Feb-91	32					0.00023	0.00132	0.00749	1.2E-06	6.5E-06
481178	8.5	May-91	33	48	0	0	48	0.00023	0.00132	0.00753	1.2E-06	6.6E-06
481178	8.5	Feb-93	56	44	0	0	44	0.00043	0.00242	0.01389	2.1E-06	1.2E-05
481178	8.5	Jul-93	61	94	0	0	94	0.00047	0.00268	0.01539	2.3E-06	1.3E-05
481178	8.5	Feb-95	80	92	0	0	92	0.00062	0.00355	0.02041	3E-06	1.7E-05
481178	8.5	Mar-95	81	57	0	0	57	0.00062	0.00355	0.02042	3E-06	1.7E-05
481183	5.7	Sep-90	188	0	0	0	0	0.3568	2.304	15	0.00313	0.01992
481183	5.7	Mar-91	194	0	0	0	0	0.3658	2.369	15.47	0.0032	0.02035
481183	5.7	Oct-91	201	4	0	0	4	0.4117	2.664	17.38	0.0036	0.02294
481183	5.7	Nov-91	202	11	0	0	11	0.4123	2.669	17.42	0.00361	0.02296
481183	5.7	Jan-93	216	19	0	0	19	0.4789	3.095	20.18	0.0042	0.02672
481183	5.7	Jul-93	222	3	0	0	3	0.5146	3.326	21.67	0.00452	0.02872
481183	5.7	Apr-94	231	3	0	0	3	0.553	3.582	23.4	0.00483	0.0308
483749	1.8	Oct-90	116	0	0	0	0	2.372	15.47	101.6	0.02239	0.1438
483749	1.8	Apr-91	122	0	0	0	0	2.427	15.86	104.3	0.02278	0.1466
483749	1.8	Aug-91	126	0	0	0	0	2.485	16.24	106.8	0.02325	0.1496
483749	1.8	Mar-92	133					2.552	16.71	110.1	0.02374	0.153
483749	1.8	Feb-93	144	0	0	0	0	2.679	17.57	115.9	0.02471	0.1595
483749	1.8	Mar-93	145	0	0	0	0	2.688	17.63	116.4	0.02477	0.1599
483749	1.8	Feb-95	168					2.943	19.36	128.2	0.02671	0.173
483749	1.8	Mar-95	169	0	0	0	0	2.953	19.43	128.7	0.02678	0.1734
483749	1.8	Mar-97	193	2	0	0	2	3.222	21.25	141.1	0.02883	0.1872
489005	1.2	Oct-90	50	169	0	0	169	902.6	5558	34470	17.41	106.4
489005	1.2	Mar-91	55	215	0	0	215	1010	6268	39160	19.32	119
489005	1.2	Aug-91	60	223	0	0	223	1093	6755	42030	20.99	128.7
489005	1.2	Feb-93	78	106	0	0	106	1454	9032	56500	27.73	170.9
489005	1.2	Apr-93	80	240	0	0	240	1498	9309	58240	28.57	176.1
489005	1.2	Feb-95	102	169	0	0	169	1907	11860	74310	36.24	223.7
489005	1.2	Feb-96	114	274	0	0	274	2130	13260	83100	40.4	249.5
489005	1.2	Jul-96	119	253	0	0	253	2221	13810	86460	42.18	260.2
489005	1.2	Jul-97	131	325	0	0	325	2459	15290	95760	46.66	288
489005	1.2	Jul-98	143	278	0	0	278	2692	16750	105000	51.06	315.3
501002	8.5	Aug-89	58					1.78	13.94	109.1	0.01544	0.1209
501002	8.5	Aug-90	70					2.951	23.12	181.2	0.02637	0.2067
501002	8.5	May-94	115	2	0	0	2	4.653	36.46	285.7	0.04141	0.3246
501002	8.5	Aug-94	118	0	0	0	0	4.655	36.48	285.8	0.04143	0.3247
501002	8.5	Apr-95	126	8	0	0	8	4.738	37.12	290.9	0.04199	0.3292

Table D-1 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using Shell Oil Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})				
				Low	Medium	High	Total	0.9,0.9	0.9,1.0	0.9,1.1	1.0,0.9	1.0,1.0
501002	8.5	Oct-96	144	16	0	0	16	5.178	40.58	318	0.04568	0.3581
501002	8.5	May-97	151	66	125	0	191	7.446	58.37	457.5	0.06957	0.5454
501002	8.5	Oct-97	156	10	5	0	14	7.447	58.37	457.5	0.06957	0.5454
501002	8.5	Jun-98	164	10	26	0	36	7.533	59.05	462.9	0.07015	0.55
501004	8	Apr-93	102					11.95	99.79	833	0.1234	1.03
501004	8	Oct-95	132					12.19	101.7	849.3	0.125	1.043
501004	8	Nov-97	157					20.29	169.4	1414	0.2086	1.742
511002	5.7	Apr-89	115					1.951	16.64	142.2	0.01571	0.1343
511023	10.1	Oct-89	107					0.1758	1.368	10.69	0.00105	0.0082
511023	10.1	Mar-91	124					0.3075	2.411	18.95	0.00184	0.01448
511023	10.1	May-92	138	0	0	0	0	0.3095	2.423	19.03	0.00185	0.01454
511023	10.1	Oct-92	143	21	0	0	21	0.3108	2.432	19.08	0.00186	0.01458
511023	10.1	Dec-93	157	0	0	0	0	0.3939	3.086	24.25	0.00236	0.01854
511023	10.1	Sep-95	178	105	0	0	105	0.3973	3.107	24.38	0.00238	0.01864
511023	10.1	Feb-96	183	167	0	0	167	0.3974	3.108	24.38	0.00238	0.01864
511023	10.1	Mar-97	196	4	0	0	4	0.4897	3.836	30.13	0.00294	0.02306
512021	7.5	Oct-89	54					0.2437	1.944	15.54	0.00171	0.01371
512021	7.5	Mar-91	71					0.4522	3.622	29.06	0.00328	0.02636
512021	7.5	Oct-92	90	21	0	0	21	0.4926	3.936	31.52	0.00351	0.02812
531008	3.4	Jul-91	153	6	0	0	6	0.2363	1.783	13.58	0.00159	0.01184
531008	3.4	Jun-93	176	66	0	0	67	0.2655	2.003	15.25	0.00177	0.01319
531008	3.4	Jun-94	188	8	5	8	21	0.2908	2.196	16.73	0.00194	0.01447
561007	2.8	Jul-90	121					1.742	13.74	108.6	0.01673	0.132
561007	2.8	May-91	131	0	0	0	0	1.956	15.44	122	0.01876	0.1481
561007	2.8	Aug-91	134					1.958	15.45	122	0.01878	0.1482
561007	2.8	Aug-93	158	13	0	0	13	2.306	18.19	143.7	0.0224	0.1767
561007	2.8	Oct-93	160	26	0	0	26	2.313	18.24	144.1	0.02244	0.1771
561007	2.8	Dec-93	162	4	0	0	4	2.498	19.72	155.8	0.02426	0.1915
561007	2.8	Mar-94	165	6	0	0	6	2.517	19.87	157	0.02441	0.1926
561007	2.8	Apr-94	166	0	0	0	0	2.518	19.87	157	0.02441	0.1927
561007	2.8	Aug-94	170	6	0	0	6	2.52	19.88	157.1	0.02443	0.1928
561007	2.8	Feb-95	176	7	0	0	7	2.833	22.37	176.8	0.02779	0.2195
561007	2.8	May-95	179	0	0	0	0	2.834	22.37	176.9	0.0278	0.2195
561007	2.8	Sep-95	183	0	0	0	0	2.839	22.4	177	0.02785	0.2198
561007	2.8	Jun-96	192	5	0	0	5	2.872	22.67	179.1	0.0281	0.2218
561007	2.8	Oct-96	196	0	0	0	0	2.882	22.74	179.7	0.02817	0.2223
561007	2.8	Nov-96	197	2	0	0	2	2.902	22.9	180.9	0.02832	0.2235
561007	2.8	Mar-97	201	0	0	0	0	3.073	24.26	191.7	0.02997	0.2366
561007	2.8	Aug-97	206	3	0	0	3	3.077	24.28	191.9	0.03	0.2368
561007	2.8	Sep-97	207	0	0	0	0	3.077	24.28	191.9	0.03	0.2368

Table D-2 Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using Shell Oil Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})			
				Low	Medium	High	Total	1.0,1.1	1.1,0.9	1.1,1.0	1.1,1.1
11001	3.2	Sep-91	132	0	0	0	0	0.1401	2.5E-05	0.00016	0.00102
11001	3.2	Apr-92	139	16	0	0	16	0.144	2.5E-05	0.00016	0.00103
11001	3.2	Jul-92	142	14	0	0	14	0.1478	2.6E-05	0.00017	0.00106
11001	3.2	Jan-93	148	30	0	0	30	0.155	2.7E-05	0.00017	0.00111
11019	6.7	May-89	32					0.03687	6.7E-06	4E-05	0.00024
11019	6.7	Apr-90	43					0.0495	8.8E-06	5.3E-05	0.00032
11019	6.7	Jan-91	52					0.05976	1.1E-05	6.4E-05	0.00039
11019	6.7	Jun-91	57	4	0	0	4	0.06573	1.2E-05	7.1E-05	0.00043
11019	6.7	Mar-92	66					0.07575	1.3E-05	8.1E-05	0.00049
11019	6.7	Mar-93	78	139	0	0	139	0.08938	1.6E-05	9.5E-05	0.00058
11019	6.7	Jul-95	106	0	0	0	0	0.1214	2.1E-05	0.00013	0.00078
11019	6.7	Jan-98	136	0	0	0	0	0.155	2.7E-05	0.00016	0.00099
14126	13.1	Jun-89	15	0	0	0	0	0.00038	7.1E-08	4.3E-07	2.6E-06
14126	13.1	Mar-91	36	0	0	0	0	0.00096	1.6E-07	1E-06	6.2E-06
14126	13.1	Mar-93	60	0	0	0	0	0.00137	2.2E-07	1.4E-06	8.6E-06
14126	13.1	Apr-94	73	0	0	0	0	0.00163	2.7E-07	1.7E-06	1E-05
14126	13.1	Dec-95	93	0	0	0	0	0.00194	3.1E-07	1.9E-06	1.2E-05
14126	13.1	Dec-97	117	0	0	0	0	0.00235	3.7E-07	2.3E-06	1.5E-05
21001	3	May-90	83	0	0	0	0	2.471	0.0004	0.00316	0.02522
21001	3	Aug-91	98	0	0	0	0	2.481	0.0004	0.00317	0.02528
21001	3	Aug-93	122	27	0	0	27	3.075	0.00049	0.00392	0.03134
21001	3	Jun-95	144	0	0	0	0	3.661	0.00059	0.00467	0.03731
21001	3	Aug-97	170	0	0	0	0	4.251	0.00068	0.00543	0.04332
21001	3	Aug-98	182	0	0	0	0	4.835	0.00077	0.00618	0.04932
21002	3.3	May-90	68	0	0	0	0	0.166	2E-05	0.00017	0.00139
21002	3.3	Aug-91	83	6	0	0	6	0.1932	2.4E-05	0.0002	0.00162
21002	3.3	Aug-93	107	0	0	0	0	0.2477	3E-05	0.00025	0.00208
21002	3.3	Jun-95	129	0	0	0	0	0.3022	3.7E-05	0.00031	0.00253
21002	3.3	Aug-97	155	0	0	0	0	0.3569	4.4E-05	0.00036	0.00299
21002	3.3	May-98	164	0	0	0	0	0.3844	4.7E-05	0.00039	0.00322
40113	4.5	Feb-95	19	0	0	0	0	0.3625	0.00011	0.00061	0.00332
40113	4.5	Mar-95	20	11	0	0	11	0.3649	0.00011	0.00061	0.00333
40113	4.5	Aug-95	25	0	0	0	0	0.5402	0.00017	0.0009	0.00493
40113	4.5	Nov-95	28	0	0	0	0	0.5786	0.00018	0.00095	0.00522
40113	4.5	Feb-96	31	0	0	0	0	0.5924	0.00018	0.00096	0.00528
40113	4.5	Apr-96	33	0	0	0	0	0.6026	0.00018	0.00097	0.00534
40113	4.5	Jul-96	36	0	0	0	0	0.7422	0.00022	0.0012	0.00659
40113	4.5	Aug-96	37	0	0	0	0	0.8072	0.00024	0.0013	0.00718
40113	4.5	Jan-98	54	53	17	0	70	1.226	0.00034	0.0019	0.01061
40113	4.5	Apr-98	57	17	65	0	82	1.239	0.00035	0.00191	0.01067
40113	4.5	Jun-98	59	24	59	0	83	1.311	0.00037	0.00202	0.01129
40113	4.5	Oct-98	63	0	173	0	173	1.489	0.00041	0.00229	0.0128
40114	6.8	Feb-95	19	0	0	0	0	0.1174	1.6E-05	0.0001	0.00065
40114	6.8	Mar-95	20	31	0	0	31	0.1207	1.6E-05	0.0001	0.00067
40114	6.8	Aug-95	25	0	0	0	0	0.1988	2.7E-05	0.00017	0.00112

Table D-2 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using Shell Oil Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})			
				Low	Medium	High	Total	1.0,1.1	1.1,0.9	1.1,1.0	1.1,1.1
40114	6.8	Nov-95	28	0	0	0	0	0.234	3.2E-05	0.0002	0.00131
40114	6.8	Feb-96	31	7	0	0	7	0.2362	3.2E-05	0.0002	0.00132
40114	6.8	Apr-96	33	9	0	0	9	0.25	3.3E-05	0.00021	0.00139
40114	6.8	Jul-96	36	44	0	0	44	0.3118	4.2E-05	0.00027	0.00174
40114	6.8	Aug-96	37	0	0	0	0	0.3372	4.6E-05	0.00029	0.00189
40114	6.8	Jan-98	54	33	40	26	98	0.495	6.6E-05	0.00043	0.00275
40114	6.8	Apr-98	57	0	41	0	41	0.5045	6.7E-05	0.00043	0.0028
40114	6.8	Jun-98	59	0	42	0	42	0.543	7.2E-05	0.00047	0.00302
40114	6.8	Oct-98	63	38	23	0	61	0.6375	8.5E-05	0.00055	0.00355
40115	15.1	Feb-95	19	0	0	0	0	0.00191	3.3E-07	1.9E-06	1.1E-05
40115	15.1	Mar-95	20	33	0	0	33	0.00191	3.3E-07	1.9E-06	1.1E-05
40115	15.1	Jan-98	54	0	0	0	0	0.00389	5.9E-07	3.5E-06	2E-05
40116	16.2	Feb-95	19	0	0	0	0	0.00388	6.8E-07	4E-06	2.3E-05
40116	16.2	Mar-95	20	18	0	0	18	0.00388	6.8E-07	4E-06	2.3E-05
40116	16.2	Jan-98	54	0	0	0	0	0.00794	1.2E-06	7.2E-06	4.3E-05
40117	11.8	Feb-95	19	0	0	0	0	0.00236	2.6E-07	1.6E-06	1E-05
40117	11.8	Mar-95	20	14	0	0	14	0.00237	2.6E-07	1.6E-06	1E-05
40117	11.8	Jan-98	54	0	0	0	0	0.00729	7.5E-07	4.7E-06	3E-05
40118	11.7	Feb-95	19	0	0	0	0	0.00041	2.9E-08	2E-07	1.3E-06
40118	11.7	Mar-95	20	15	0	0	15	0.00041	2.9E-08	2E-07	1.3E-06
40118	11.7	Jan-98	54	0	0	0	0	0.00108	7.1E-08	4.8E-07	3.3E-06
41007	6.5	Sep-91	162	0	0	0	0	0.2548	3.6E-05	0.00023	0.00147
41007	6.5	Feb-93	163	57	0	0	57	0.2583	3.6E-05	0.00023	0.00149
41007	6.5	Sep-94	198	167	0	0	167	0.352	4.9E-05	0.00032	0.00203
41024	10.8	Nov-89	149					0.3288	4.6E-05	0.00027	0.00164
41024	10.8	Aug-90	158					0.3555	4.9E-05	0.0003	0.00177
41024	10.8	Oct-92	184	0	0	0	0	0.4472	6.1E-05	0.00037	0.00222
41024	10.8	Mar-95	213	9	0	0	9	0.5637	7.7E-05	0.00046	0.0028
41024	10.8	Jul-95	217	23	0	0	23	0.5893	8.1E-05	0.00049	0.00292
41024	10.8	Aug-95	218	127	0	0	127	0.5997	8.2E-05	0.00049	0.00297
41024	10.8	Nov-95	221	109	0	0	109	0.6062	8.3E-05	0.0005	0.003
41024	10.8	Feb-96	224	61	0	0	61	0.6062	8.3E-05	0.0005	0.003
41024	10.8	Apr-96	226	79	0	23	102	0.608	8.3E-05	0.0005	0.00301
41024	10.8	Jun-96	228	59	0	0	59	0.63	8.6E-05	0.00052	0.00312
41024	10.8	Aug-96	230	59	0	0	59	0.6713	9.2E-05	0.00055	0.00333
41024	10.8	Apr-98	250	49	0	4	53	0.7265	9.9E-05	0.00059	0.00358
41024	10.8	Jun-98	252	49	0	4	53	0.7494	0.0001	0.00061	0.00369
41024	10.8	Oct-98	256	50	0	4	54	0.8	0.00011	0.00065	0.00394
81029	4.2	Oct-91	233	0	25	0	25	0.1417	1.5E-05	0.00013	0.00105
81029	4.2	Jul-94	266	44	0	0	44	0.1594	1.7E-05	0.00014	0.00116
81029	4.2	Sep-95	280	11	0	0	11	0.161	1.7E-05	0.00014	0.00117
81053	4.6	Oct-89	60					1.315	0.00019	0.00149	0.01191
81053	4.6	Jul-90	69					1.316	0.00019	0.00149	0.01192
81053	4.6	Apr-93	102	92	0	0	92	2.33	0.00033	0.00265	0.02124
81053	4.6	Nov-93	109	18	0	0	18	2.345	0.00033	0.00266	0.02133
81053	4.6	Dec-93	110	33	0	0	33	2.345	0.00033	0.00266	0.02133
81053	4.6	Oct-94	120	108	0	0	108	2.348	0.00033	0.00266	0.02134
81053	4.6	Feb-95	124	228	0	0	228	2.348	0.00033	0.00266	0.02134

Table D-2 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using Shell Oil Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})			
				Low	Medium	High	Total	1.0,1.1	1.1,0.9	1.1,1.0	1.1,1.1
81053	4.6	May-95	127	229	0	0	229	2.348	0.00033	0.00266	0.02134
81053	4.6	May-96	139	0	0	0	0	2.364	0.00033	0.00268	0.02144
81053	4.6	Oct-96	144	0	0	0	0	2.725	0.00039	0.00312	0.02471
81053	4.6	Nov-96	145	33	0	0	33	2.725	0.00039	0.00312	0.02471
81053	4.6	Mar-97	149	45	0	0	45	2.725	0.00039	0.00312	0.02471
91803	7.2	Jul-89	49					4.423	0.00075	0.00612	0.04961
91803	7.2	Sep-90	63					4.893	0.00081	0.0066	0.05356
91803	7.2	Aug-91	74	7	0	0	7	10.22	0.00175	0.01423	0.1154
91803	7.2	Sep-92	87	5	0	0	5	10.37	0.00177	0.01437	0.1165
91803	7.2	May-94	107	103	0	0	103	18.23	0.00313	0.02538	0.2058
91803	7.2	May-95	119	207	7	0	214	18.42	0.00315	0.02556	0.2073
91803	7.2	Oct-96	136	364	0	0	364	18.54	0.00316	0.02567	0.2082
91803	7.2	May-97	143	557	0	0	557	19.23	0.00325	0.02634	0.2137
91803	7.2	Sep-97	147	74	0	0	74	19.23	0.00325	0.02634	0.2137
91803	7.2	Jun-98	156	279	11	0	290	29.72	0.0051	0.04136	0.3355
120103	12	Dec-96	14	0	0	0	0	6.3E-06	4.2E-10	2.8E-09	1.9E-08
120104	18	Dec-96	14	0	0	0	0	5.8E-05	6.2E-09	4E-08	2.5E-07
120105	7.9	Dec-96	14	0	0	0	0	0.00071	7.4E-08	4.8E-07	3.1E-06
120106	15	Dec-96	14	0	0	0	0	4.3E-05	4.7E-09	3E-08	1.9E-07
123995	5	Apr-92	197	34	0	0	34	1.186	9.3E-05	0.00068	0.00496
123995	5	Mar-94	220	82	0	0	82	1.336	0.0001	0.00076	0.00558
123995	5	Jan-96	242	215	0	0	215	1.476	0.00012	0.00084	0.00616
123995	5	Jan-96	243	72	0	0	72	1.484	0.00012	0.00085	0.00619
123997	3.1	Aug-90	195					0.6035	0.00014	0.00086	0.0053
123997	3.1	Oct-91	209					0.6765	0.00016	0.00097	0.00595
123997	3.1	Mar-93	226					0.7412	0.00017	0.00105	0.00649
123997	3.1	Mar-94	238					0.7994	0.00018	0.00113	0.00699
124105	2.3	Apr-89	53	0	0	0	0	30.78	0.00984	0.06032	0.3714
124105	2.3	Oct-91	83	0	0	0	0	52.39	0.01658	0.102	0.6302
124105	2.3	Mar-93	100	0	0	0	0	60.95	0.01909	0.1177	0.7291
124106	8.2	Apr-89	21					0.00742	6.8E-07	4.4E-06	2.9E-05
124106	8.2	Feb-91	43					0.01765	1.6E-06	1E-05	6.9E-05
124106	8.2	Jul-91	48	0	0	0	0	0.0203	1.8E-06	1.2E-05	7.9E-05
124106	8.2	Mar-94	80	10	0	0	10	0.03583	3.1E-06	2.1E-05	0.00014
124106	8.2	Jan-97	114	50	0	0	50	0.05316	4.6E-06	3.1E-05	0.0002
124107	2.7	Dec-89	75	0	0	0	0	0.3834	9E-05	0.00057	0.00365
124107	2.7	Feb-91	89	261	0	0	261	0.449	0.0001	0.00066	0.00423
124107	2.7	Jul-91	94	343	0	0	343	0.4876	0.00011	0.00072	0.0046
124107	2.7	Mar-93	114	18	0	0	18	0.6107	0.00014	0.00089	0.00573
124107	2.7	Mar-94	126	37	13	0	51	0.6844	0.00015	0.00099	0.00638
124107	2.7	Jan-96	148	67	0	0	67	0.8469	0.00019	0.00122	0.00787
124107	2.7	Mar-97	162	0	0	0	0	0.9453	0.00021	0.00136	0.00875
124108	9.9	Apr-89	35	0	0	0	0	0.00096	1.6E-07	9.9E-07	6.2E-06
124108	9.9	Jan-91	56	0	0	0	0	0.00117	1.9E-07	1.2E-06	7.3E-06
124108	9.9	Oct-91	65	0	0	0	0	0.00174	2.5E-07	1.6E-06	1E-05
124108	9.9	Mar-94	94	7	0	0	7	0.00198	2.8E-07	1.8E-06	1.2E-05
124108	9.9	Aug-94	99	0	0	0	0	0.0026	3.5E-07	2.3E-06	1.5E-05
124108	9.9	Jan-96	116	0	0	0	0	0.00273	3.6E-07	2.4E-06	1.6E-05

Table D-2 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using Shell Oil Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})			
				Low	Medium	High	Total	1.0,1.1	1.1,0.9	1.1,1.0	1.1,1.1
124135	1.4	Dec-89	227	99	199	0	298	10540	3.985	26.7	181.2
124135	1.4	Jan-91	240	412	271	0	683	10890	4.122	27.6	187.1
131031	11.1	Apr-91	119					0.00196	1.3E-07	1.1E-06	8.7E-06
131031	11.1	Jul-92	134					0.00197	1.3E-07	1.1E-06	8.7E-06
131031	11.1	Jan-93	140					0.00284	1.9E-07	1.6E-06	1.3E-05
131031	11.1	Apr-94	155					0.00345	2.3E-07	1.9E-06	1.5E-05
131031	11.1	Oct-94	161					0.00346	2.3E-07	1.9E-06	1.5E-05
131031	11.1	Aug-95	171					0.00347	2.3E-07	1.9E-06	1.5E-05
131031	11.1	Jan-96	176					0.00473	3.2E-07	2.6E-06	2.1E-05
131031	11.1	Apr-96	179					0.00473	3.2E-07	2.6E-06	2.1E-05
134111	8.7	Mar-89	101	27	0	0	27	0.00338	2.1E-07	1.7E-06	1.4E-05
134111	8.7	Mar-91	125	291	0	0	291	0.00574	3.5E-07	2.8E-06	2.3E-05
134111	8.7	Feb-92	136	477	0	0	477	0.00577	3.5E-07	2.8E-06	2.3E-05
134112	15.9	May-89	144	0	0	0	0	0.00898	2.7E-06	1.5E-05	8.8E-05
134112	15.9	Feb-91	165	17	0	0	17	0.00999	2.9E-06	1.7E-05	9.5E-05
134112	15.9	Apr-91	167	0	0	0	0	0.00999	2.9E-06	1.7E-05	9.5E-05
134112	15.9	Feb-94	201	0	0	0	0	0.01513	4.3E-06	2.5E-05	0.00014
134112	15.9	Oct-94	209	0	0	0	0	0.01585	4.4E-06	2.6E-05	0.00015
134112	15.9	Jan-96	224	0	0	0	0	0.01655	4.6E-06	2.7E-05	0.00016
134112	15.9	Feb-97	237	0	0	0	0	0.01919	5.3E-06	3.1E-05	0.00018
134112	15.9	Apr-98	251	0	0	0	0	0.01995	5.5E-06	3.2E-05	0.00019
134113	15.2	May-89	144	0	0	0	0	0.02803	9.9E-06	5.5E-05	0.0003
134113	15.2	Feb-91	165	0	0	0	0	0.0306	1E-05	5.8E-05	0.00033
134113	15.2	Apr-91	167	0	0	0	0	0.03061	1E-05	5.8E-05	0.00033
134113	15.2	Feb-94	201	0	0	0	0	0.04527	1.5E-05	8.6E-05	0.00048
134113	15.2	Oct-94	209	0	0	0	0	0.04722	1.6E-05	8.9E-05	0.0005
134113	15.2	Jan-96	224	0	0	0	0	0.04909	1.6E-05	9.1E-05	0.00052
134113	15.2	Feb-97	237	31	0	0	31	0.0564	1.9E-05	0.00011	0.00059
134113	15.2	Apr-98	251	37	0	0	37	0.05861	1.9E-05	0.00011	0.00061
161001	3.7	Jul-89	192	155	0	0	155	1.559	0.00014	0.00121	0.01017
161001	3.7	Aug-90	205	193	0	0	193	1.672	0.00015	0.00129	0.01084
161001	3.7	Jun-93	239	78	0	0	78	2.086	0.00019	0.00159	0.01339
161001	3.7	Aug-94	253	199	0	0	199	2.18	0.0002	0.00165	0.01389
161001	3.7	May-95	262	183	2	0	185	2.527	0.00023	0.00192	0.01618
161001	3.7	Jul-97	288	67	63	44	175	2.672	0.00024	0.00201	0.01692
161001	3.7	Sep-98	302	0	159	5	164	3.072	0.00028	0.00232	0.01954
161009	10.4	Sep-89	180					0.7338	0.00011	0.00084	0.00666
161009	10.4	Jul-90	190					0.8756	0.00013	0.00099	0.00782
161009	10.4	Jul-92	214	0	0	0	0	0.8964	0.00013	0.00101	0.00795
161009	10.4	Oct-93	229	8	0	0	8	1.071	0.00015	0.00119	0.00938
161009	10.4	Jun-96	261	1	0	0	1	1.116	0.00015	0.00122	0.00967
161009	10.4	Jul-97	274	0	0	0	0	1.34	0.00018	0.00146	0.0115
161021	5.9	Sep-89	48					0.02961	3.5E-06	2.8E-05	0.00023
161021	5.9	Oct-90	61	0	0	0	0	0.02992	3.6E-06	2.9E-05	0.00023
161021	5.9	Aug-91	71	0	0	0	0	0.05942	7.1E-06	5.7E-05	0.00046
161021	5.9	Aug-93	95	0	0	0	0	0.05998	7.2E-06	5.7E-05	0.00046
161021	5.9	Sep-95	120	0	0	0	0	0.09091	1.1E-05	8.7E-05	0.0007
161021	5.9	Jun-96	129	5	0	0	5	0.09109	1.1E-05	8.7E-05	0.0007

Table D-2 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using Shell Oil Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})			
				Low	Medium	High	Total	1.0,1.1	1.1,0.9	1.1,1.0	1.1,1.1
161021	5.9	Jul-97	142	0	0	0	0	0.09145	1.1E-05	8.7E-05	0.0007
169034	9.2	Jul-89	10					0.00048	3.1E-08	2.4E-07	1.8E-06
169034	9.2	Aug-90	23					0.01224	1.1E-06	8.7E-06	6.9E-05
169034	9.2	Jun-93	57	12	0	0	12	0.1164	1.2E-05	9.8E-05	0.00078
169034	9.2	Aug-94	71	146	0	0	146	0.2067	2.2E-05	0.00018	0.00141
169034	9.2	May-95	80					0.2072	2.2E-05	0.00018	0.00141
169034	9.2	Jul-97	106	217	0	0	217	0.3072	3.3E-05	0.00026	0.0021
169034	9.2	Sep-98	120	156	52	18	226	0.3078	3.3E-05	0.00026	0.0021
201009	11.1	Aug-88	44	0	0	0	0	16.65	0.00258	0.02135	0.1769
201009	11.1	May-89	53	11	0	0	11	16.76	0.00259	0.02144	0.1777
201009	11.1	Dec-90	72	210	5	0	215	30.32	0.00476	0.03942	0.3267
201009	11.1	Oct-91	82	6	1	0	7	32.81	0.00511	0.04231	0.3506
201009	11.1	Apr-93	100	9	0	0	9	44.83	0.00705	0.05844	0.4843
201009	11.1	Apr-95	124	16	28	0	43	52.67	0.00817	0.06773	0.5613
201009	11.1	Apr-96	136	0	0	0	0	52.99	0.00821	0.06803	0.5638
201009	11.1	Jan-99	168	0	0	0	0	60.91	0.00928	0.07694	0.6376
251003	6.6	Aug-89	180	758	0	0	758	1.288	0.00021	0.00168	0.01337
251003	6.6	Sep-90	193	691	0	0	691	1.544	0.00025	0.00199	0.01591
251003	6.6	Aug-91	204	556	1	0	557	1.551	0.00025	0.002	0.01596
251003	6.6	Sep-92	217	600	0	0	600	1.576	0.00025	0.00202	0.01615
251003	6.6	Oct-95	254	563	0	0	563	1.87	0.0003	0.00238	0.01901
251003	6.6	Oct-96	266	39	0	0	39	1.897	0.0003	0.00241	0.01921
251003	6.6	Jun-98	286	32	9	0	41	2.21	0.00035	0.00279	0.02229
251004	9.6	Aug-89	178	0	0	0	0	0.2724	3.5E-05	0.00027	0.00213
251004	9.6	Sep-90	191	19	0	0	19	0.2948	3.8E-05	0.00029	0.00229
251004	9.6	Aug-91	202	16	0	0	16	0.3454	4.4E-05	0.00034	0.00269
251004	9.6	Sep-92	215	0	0	0	0	0.346	4.4E-05	0.00034	0.00269
251004	9.6	Oct-95	252	0	0	0	0	0.5002	6.3E-05	0.00049	0.00387
251004	9.6	Jun-97	272	3	0	0	3	0.5344	6.7E-05	0.00053	0.0041
251004	9.6	Jun-98	284	3	0	0	3	0.6137	7.7E-05	0.0006	0.00472
261001	2.2	Jul-88	203	0	0	0	0	0.1655	3.1E-05	0.00021	0.00153
261001	2.2	Sep-89	217	16	0	0	16	0.1797	3.3E-05	0.00023	0.00166
261001	2.2	Jul-90	227	24	0	0	24	0.1888	3.5E-05	0.00024	0.00174
261001	2.2	Jul-91	239	0	0	0	0	0.1949	3.6E-05	0.00025	0.0018
261001	2.2	Sep-91	241	51	0	0	51	0.1966	3.6E-05	0.00026	0.00182
261001	2.2	Sep-92	253	0	0	0	0	0.2011	3.7E-05	0.00026	0.00186
261001	2.2	Jun-93	262	23	0	0	23	0.2103	3.9E-05	0.00027	0.00194
261001	2.2	Jun-93	263	0	0	0	0	0.2118	3.9E-05	0.00027	0.00195
261001	2.2	May-95	285	9	0	0	9	0.2234	4.1E-05	0.00029	0.00206
261001	2.2	Jul-96	299	5	0	0	5	0.2378	4.4E-05	0.00031	0.0022
261004	4.2	Sep-89	51	321	0	0	321	5.445	0.00104	0.00805	0.06232
261004	4.2	Jul-90	61	451	0	0	451	8.712	0.0017	0.01318	0.102
271018	4.4	Apr-89	124	0	0	0	0	24.34	0.00347	0.02866	0.2368
271018	4.4	Jun-89	126					24.34	0.00347	0.02866	0.2368
271018	4.4	Oct-90	142					24.93	0.00354	0.02924	0.2416
271018	4.4	Jun-93	174	41	1	0	41	33.74	0.00484	0.03995	0.3301
271018	4.4	Jul-93	176	7	51	0	57	33.74	0.00484	0.03995	0.3301
271018	4.4	Mar-94	183	58	39	0	98	37.9	0.00546	0.04513	0.3729

Table D-2 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using Shell Oil Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})			
				Low	Medium	High	Total	1.0,1.1	1.1,0.9	1.1,1.0	1.1,1.1
271018	4.4	Aug-94	188	131	0	0	131	37.9	0.00546	0.04514	0.3729
271087	15.7	Oct-91	154	0	0	0	0	16.13	0.00253	0.0202	0.1613
271087	15.7	May-93	173	8	0	0	8	18.23	0.00285	0.02277	0.1819
271087	15.7	Oct-94	190	24	0	0	24	19.11	0.00299	0.02386	0.1906
271087	15.7	Jun-96	210	25	0	0	25	21.84	0.00342	0.02729	0.2179
291008	11.4	Feb-92	70	0	0	0	0	0.3999	4.4E-05	0.00035	0.00277
291008	11.4	Mar-93	83	58	3	0	61	0.3999	4.4E-05	0.00035	0.00277
291008	11.4	Mar-93	83	28	34	0	62	7.005	0.0013	0.00803	0.04975
291008	11.4	Apr-96	120	130	0	0	130	0.6307	6.9E-05	0.00055	0.00434
291008	11.4	Feb-00	152	26	0	0	26	0.8257	8.8E-05	0.0007	0.00558
307088	4.9	Sep-89	100	0	0	0	0	0.2634	3.2E-05	0.00025	0.00206
307088	4.9	May-91	120	4	12	0	16	0.2847	3.4E-05	0.00027	0.0022
308129	3.2	Oct-89	17					0.1123	1.6E-05	0.00013	0.00099
308129	3.2	Jul-91	38					0.221	3.1E-05	0.00025	0.00194
308129	3.2	Jul-92	50	0	0	0	0	0.3344	4.7E-05	0.00037	0.00293
308129	3.2	Aug-93	63	0	0	0	0	0.5042	7.2E-05	0.00057	0.00447
308129	3.2	Dec-93	67	0	0	0	0	0.5044	7.2E-05	0.00057	0.00447
308129	3.2	Mar-94	70	0	0	0	0	0.5057	7.2E-05	0.00057	0.00448
308129	3.2	Oct-94	77	0	0	0	0	0.5078	7.3E-05	0.00057	0.00449
308129	3.2	Feb-95	81	0	0	0	0	0.6327	9E-05	0.00071	0.00558
308129	3.2	May-95	84	0	0	0	0	0.6361	9.1E-05	0.00071	0.00561
308129	3.2	Jun-96	97	0	0	0	0	0.8291	0.00012	0.00093	0.00736
308129	3.2	Oct-96	101	0	0	0	0	0.8303	0.00012	0.00094	0.00737
308129	3.2	Jan-97	104	0	0	0	0	0.8314	0.00012	0.00094	0.00737
308129	3.2	Mar-97	106	0	0	0	0	0.8319	0.00012	0.00094	0.00738
308129	3.2	Aug-97	111	0	0	0	0	0.8341	0.00012	0.00094	0.00739
308129	3.2	Oct-97	113	0	0	0	0	0.8343	0.00012	0.00094	0.00739
321020	7	Jul-91	86	34	0	0	34	4.376	0.00062	0.00513	0.04269
321020	7	Aug-93	111	138	0	0	138	7.189	0.00102	0.00851	0.07076
321020	7	Sep-94	123	29	20	0	49	7.369	0.00104	0.00866	0.07208
321020	7	Apr-95	131	242	0	0	242	7.471	0.00105	0.00874	0.07273
321020	7	Jun-97	157	9	0	0	9	9.216	0.00127	0.01057	0.08795
321020	7	Jun-98	169	0	0	0	0	9.334	0.00128	0.01066	0.0887
341031	7.3	Apr-92	224	333	1	0	333	4.157	0.00062	0.00482	0.03783
341031	7.3	Feb-93	234	322	31	3	356	4.183	0.00062	0.00485	0.03803
341031	7.3	Oct-95	266	0	352	170	522	4.33	0.00064	0.005	0.03906
341031	7.3	Nov-95	267	232	30	0	261	5.64	0.00082	0.00644	0.05052
341033	7.4	Apr-92	211	52	2	0	54	0.07319	8.4E-06	6.8E-05	0.00054
341033	7.4	Feb-93	221	32	11	0	44	0.07511	8.6E-06	6.9E-05	0.00056
341033	7.4	Nov-95	254	55	0	0	55	0.09457	1.1E-05	8.7E-05	0.0007
341033	7.4	Jul-97	274	260	0	0	260	0.09659	1.1E-05	8.9E-05	0.00071
341034	11.1	Oct-89	48	0	0	0	0	2.109	0.00029	0.00229	0.01832
341034	11.1	Sep-90	59	0	0	0	0	2.109	0.00029	0.00229	0.01833
341034	11.1	Apr-92	78	0	0	0	0	3.328	0.00044	0.00355	0.02843
341034	11.1	Feb-93	88	0	0	0	0	3.329	0.00044	0.00355	0.02843
341034	11.1	Nov-95	121	3	0	0	3	4.763	0.00063	0.00503	0.04031
341034	11.1	Jul-97	141	0	15	0	15	6.255	0.00082	0.00658	0.05274
350101	7.2	May-97	19	0	0	0	0	0.1463	1.5E-05	0.00011	0.00083

Table D-2 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using Shell Oil Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})			
				Low	Medium	High	Total	1.0,1.1	1.1,0.9	1.1,1.0	1.1,1.1
350102	4.8	May-97	19	0	0	0	0	0.4566	4.7E-05	0.00035	0.00272
350103	12.5	May-97	19	0	0	0	0	0.01515	9.5E-07	7.8E-06	6.4E-05
350104	19.2	May-97	19	0	0	0	0	3.8E-05	6E-09	3.5E-08	2E-07
350105	9.9	May-97	19	0	0	0	0	0.02557	1.7E-06	1.4E-05	0.00011
350106	15.6	May-97	19	0	0	0	0	0.01036	7E-07	5.6E-06	4.4E-05
351005	8.9	Oct-89	73	0	0	0	0	0.05176	4.8E-06	3.8E-05	0.00031
351005	8.9	Mar-91	90	0	0	0	0	0.08791	8.1E-06	6.5E-05	0.00053
351005	8.9	Oct-92	109	0	0	0	0	0.0931	8.6E-06	6.9E-05	0.00055
351005	8.9	Feb-94	125	0	0	0	0	0.1019	9.4E-06	7.5E-05	0.0006
351005	8.9	Mar-95	138	0	0	0	0	0.1508	1.4E-05	0.00011	0.00089
351005	8.9	Apr-97	163	0	0	0	0	0.1649	1.5E-05	0.00012	0.00096
351022	6.3	Oct-89	37	0	0	0	0	0.08996	9.8E-06	7.9E-05	0.00064
351022	6.3	Mar-91	54	0	0	0	0	0.2308	2.5E-05	0.0002	0.00164
351022	6.3	Oct-92	73	0	0	0	0	0.2353	2.5E-05	0.0002	0.00166
351022	6.3	Feb-94	89	0	0	0	0	0.4241	4.5E-05	0.00037	0.00299
351022	6.3	Mar-95	102	0	0	0	0	0.4273	4.6E-05	0.00037	0.00301
351022	6.3	Apr-97	127	0	0	0	0	0.8409	9.1E-05	0.00074	0.00603
351112	6.3	Dec-89	67					0.05093	5.5E-06	3.8E-05	0.00026
351112	6.3	Jan-91	80					0.06073	6.5E-06	4.5E-05	0.00031
351112	6.3	Mar-91	82	0	0	0	0	0.06113	6.6E-06	4.5E-05	0.00031
351112	6.3	Jan-93	104	0	0	0	0	0.07958	8.6E-06	5.9E-05	0.00041
351112	6.3	Feb-94	117	0	0	0	0	0.08942	9.6E-06	6.6E-05	0.00046
351112	6.3	Oct-94	125	0	0	0	0	0.09748	1E-05	7.2E-05	0.0005
351112	6.3	Mar-95	130	14	0	0	14	0.09989	1.1E-05	7.3E-05	0.00051
351112	6.3	Apr-95	131	0	0	0	0	0.1004	1.1E-05	7.3E-05	0.00051
351112	6.3	Jun-95	133	0	0	0	0	0.1028	1.1E-05	7.5E-05	0.00052
351112	6.3	Nov-96	150	0	0	0	0	0.1172	1.3E-05	8.6E-05	0.0006
351112	6.3	Apr-97	155	0	0	0	0	0.119	1.3E-05	8.7E-05	0.0006
351112	6.3	Sep-97	160	0	0	0	0	0.1253	1.3E-05	9.2E-05	0.00064
371024	4.8	Nov-89	109					0.03446	3.9E-06	3.2E-05	0.00026
371024	4.8	Mar-91	125					0.05798	6.6E-06	5.4E-05	0.00044
371024	4.8	Apr-92	138	3	0	0	3	0.05872	6.7E-06	5.4E-05	0.00044
371802	4.5	Mar-91	66					0.09368	2.1E-05	0.00013	0.00086
371802	4.5	Oct-92	85	28	0	0	28	0.1239	2.7E-05	0.00018	0.00114
371802	4.5	Apr-94	103	0	0	0	0	0.1431	3.1E-05	0.0002	0.00132
371802	4.5	Jul-95	118	41	0	0	41	0.1654	3.6E-05	0.00023	0.00152
371802	4.5	Apr-96	127	0	0	0	0	0.1755	3.8E-05	0.00025	0.00161
371992	2.4	Mar-91	14					0.06365	1.5E-05	9.3E-05	0.00059
371992	2.4	Oct-92	33	22	0	0	22	0.2	4.9E-05	0.0003	0.00192
371992	2.4	Apr-94	51	0	0	0	0	0.3339	7E-05	0.00045	0.00297
371992	2.4	Feb-96	73	0	0	0	0	0.5915	0.00012	0.00078	0.00521
404087	10.1	Jan-90	43	0	0	0	0	0.00022	2.1E-08	1.5E-07	1.1E-06
404087	10.1	Oct-91	64	0	0	0	0	0.00049	4.4E-08	3.2E-07	2.3E-06
404087	10.1	Nov-92	77	31	0	0	31	0.0005	4.5E-08	3.2E-07	2.4E-06
404087	10.1	Feb-93	80	35	0	0	35	0.0005	4.5E-08	3.2E-07	2.4E-06
404087	10.1	Nov-94	101	143	0	0	143	0.00083	7.3E-08	5.3E-07	3.9E-06
404087	10.1	Feb-95	104	112	0	0	112	0.00083	7.3E-08	5.3E-07	3.9E-06
404087	10.1	Aug-95	110	0	159	0	159	0.00084	7.4E-08	5.4E-07	3.9E-06

Table D-2 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using Shell Oil Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})			
				Low	Medium	High	Total	1.0,1.1	1.1,0.9	1.1,1.0	1.1,1.1
404087	10.1	Jun-97	132	10	0	0	10	0.00086	7.8E-08	5.6E-07	4.1E-06
404163	11.5	Jan-90	34					0.1541	1.4E-05	0.00012	0.00095
404163	11.5	Mar-91	48					0.1564	1.4E-05	0.00012	0.00096
404163	11.5	Oct-91	55	0	0	0	0	0.1564	1.4E-05	0.00012	0.00096
404163	11.5	Nov-92	68	0	0	0	0	0.3281	3E-05	0.00025	0.00204
404163	11.5	Mar-93	72	7	0	0	7	0.3282	3E-05	0.00025	0.00204
404163	11.5	Nov-94	92	0	0	0	0	0.3306	3E-05	0.00025	0.00205
404163	11.5	Apr-96	109	0	0	0	0	0.5047	4.6E-05	0.00038	0.00313
404163	11.5	Aug-97	125	45	8	0	53	0.5047	4.6E-05	0.00038	0.00313
404163	11.5	Jan-99	141	6	9	0	15	0.6701	6.2E-05	0.00051	0.00416
404165	8.1	Jan-90	68					2.896	0.00029	0.00242	0.02002
404165	8.1	Mar-91	82					3.029	0.0003	0.00251	0.0208
404165	8.1	Oct-91	89	4	0	0	4	3.03	0.0003	0.00252	0.02081
404165	8.1	Nov-92	102	5	0	0	5	4.563	0.00046	0.00381	0.03155
404165	8.1	Mar-93	106	19	0	0	19	4.566	0.00046	0.00382	0.03157
404165	8.1	Oct-94	125	9	0	0	9	4.708	0.00047	0.00392	0.0324
404165	8.1	Nov-94	126	16	0	0	16	4.709	0.00047	0.00392	0.0324
404165	8.1	Apr-95	131	24	0	0	24	4.851	0.00049	0.00402	0.03324
404165	8.1	Jun-95	133	25	0	0	25	4.851	0.00049	0.00402	0.03324
404165	8.1	Apr-96	143	25	0	0	25	6.492	0.00065	0.00541	0.04474
404165	8.1	Nov-96	150	60	0	0	60	6.493	0.00065	0.00541	0.04475
404165	8.1	May-97	156	26	0	0	26	6.497	0.00065	0.00541	0.04476
404165	8.1	Sep-97	160	24	0	0	24	6.497	0.00065	0.00541	0.04476
421599	12.3	Aug-89	25					8.459	0.00133	0.01093	0.08985
421599	12.3	Sep-90	38					13.93	0.00222	0.01828	0.1503
421599	12.3	Mar-93	68	0	0	0	0	30.46	0.00486	0.03996	0.3285
421599	12.3	Sep-94	86	0	0	0	0	30.67	0.00488	0.04015	0.33
421599	12.3	Jun-95	95	8	0	0	8	42.45	0.00675	0.05545	0.4559
421599	12.3	Jul-96	108	4	0	0	4	50.21	0.00802	0.06589	0.5416
421599	12.3	Mar-98	128	2	0	0	2	50.73	0.00807	0.06634	0.5453
451011	3.2	Mar-92	69	0	0	0	0	0.3146	6.8E-05	0.00042	0.00255
451011	3.2	Oct-92	76	0	0	0	0	0.374	8.1E-05	0.0005	0.00305
451011	3.2	Jun-93	84	0	0	0	0	0.3924	8.4E-05	0.00052	0.00318
451011	3.2	Jan-96	115	16	0	0	16	0.5299	0.00011	0.00069	0.00428
451011	3.2	Jun-97	132	0	0	0	0	0.5981	0.00013	0.00078	0.00481
451011	3.2	Feb-99	150	0	0	0	0	0.6938	0.00015	0.0009	0.00559
473104	1.3	Aug-89	39					2.495	0.0014	0.0087	0.0545
473104	1.3	Nov-89	42					2.517	0.0014	0.00874	0.05478
473104	1.3	May-91	60					2.637	0.00143	0.00895	0.05629
473104	1.3	Aug-91	63					2.657	0.00144	0.009	0.05658
473104	1.3	Oct-92	77					2.785	0.00147	0.00924	0.05826
473104	1.3	Aug-93	87					2.874	0.0015	0.0094	0.05941
473104	1.3	Nov-95	114					3.248	0.0016	0.01013	0.06448
473104	1.3	Oct-96	125					3.394	0.00164	0.01041	0.06642
480001	2.4	Apr-89	1					0.1116	4.9E-05	0.00027	0.00154
480001	2.4	Oct-90	19					4.419	0.00207	0.01152	0.06448
480001	2.4	May-91	26	0	0	0	0	4.962	0.00225	0.0126	0.07093
480001	2.4	Feb-93	47	0	0	0	0	10.34	0.00458	0.02584	0.1465

Table D-2 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using Shell Oil Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})			
				Low	Medium	High	Total	1.0,1.1	1.1,0.9	1.1,1.0	1.1,1.1
480001	2.4	Apr-93	49	0	0	0	0	10.6	0.00467	0.02635	0.1495
480001	2.4	Feb-95	71	0	0	0	0	16.74	0.00711	0.04054	0.232
480001	2.4	Mar-95	72	0	0	0	0	16.83	0.00714	0.0407	0.233
480001	2.4	May-97	98	34	0	0	34	24.47	0.01005	0.05773	0.3329
480001	2.4	Mar-98	108	34	0	0	34	28.37	0.01162	0.06681	0.3856
481060	7.5	Jun-90	52	0	0	0	0	2.307	0.00034	0.00211	0.01325
481060	7.5	Feb-91	60	0	0	0	0	2.786	0.00041	0.00254	0.01596
481060	7.5	Apr-91	62	0	0	0	0	2.861	0.00042	0.0026	0.01633
481060	7.5	Mar-92	73	12	0	0	12	3.612	0.00052	0.00328	0.0206
481060	7.5	Feb-93	84	19	0	0	19	4.39	0.00063	0.00397	0.02499
481060	7.5	Mar-93	85	23	0	0	23	4.408	0.00063	0.00398	0.02507
481060	7.5	Oct-94	104	14	0	0	14	6.258	0.00089	0.00562	0.03549
481060	7.5	Feb-95	108	28	0	0	28	6.31	0.0009	0.00566	0.03572
481060	7.5	Mar-95	109	0	0	0	0	6.332	0.0009	0.00567	0.03582
481060	7.5	Mar-95	112	14	0	0	14	6.624	0.00094	0.00592	0.03741
481060	7.5	Jun-95	134	8	0	0	8	8.498	0.0012	0.00756	0.04786
481060	7.5	Apr-97	137	31	0	0	31	9.005	0.00127	0.00802	0.05076
481060	7.5	Jul-97	139	31	2	0	33	9.405	0.00133	0.00839	0.05308
481060	7.5	Sep-97	154	32	0	0	32	10.78	0.00152	0.00957	0.06066
481077	5.1	Apr-89	88					0.6544	7.2E-05	0.00055	0.00429
481077	5.1	Nov-91	119	0	0	0	0	0.9757	0.00011	0.00083	0.0064
481077	5.1	Oct-92	130	28	0	0	28	1.073	0.00012	0.0009	0.007
481077	5.1	May-93	137	124	0	0	124	1.077	0.00012	0.00091	0.00701
481077	5.1	Oct-94	154	143	0	0	143	1.086	0.00012	0.00091	0.00705
481077	5.1	Mar-95	159	47	0	0	47	1.363	0.00015	0.00114	0.00883
481077	5.1	Apr-95	160	181	0	0	181	1.363	0.00015	0.00114	0.00883
481077	5.1	Jun-95	162	181	0	0	181	1.364	0.00015	0.00114	0.00884
481077	5.1	Aug-95	164	181	0	0	181	1.365	0.00015	0.00114	0.00884
481077	5.1	Jun-96	174	181	0	0	181	1.371	0.00015	0.00115	0.00886
481077	5.1	May-97	185	228	10	0	238	1.378	0.00015	0.00115	0.00889
481077	5.1	Jul-97	187	300	0	0	300	1.379	0.00015	0.00115	0.0089
481077	5.1	Sep-97	189	276	0	0	276	1.379	0.00015	0.00115	0.0089
481077	5.1	Mar-98	195	281	0	0	281	1.688	0.00018	0.00141	0.01089
481109	6.5	Jan-90	68					0.6876	0.00021	0.00114	0.00626
481109	6.5	Sep-90	76					0.7775	0.00024	0.00128	0.00703
481109	6.5	May-91	84	123	0	0	123	0.8839	0.00026	0.00143	0.00791
481109	6.5	Feb-93	105	148	0	0	148	1.163	0.00033	0.00184	0.01024
481109	6.5	Jul-93	110	336	0	0	336	1.227	0.00035	0.00193	0.01079
481109	6.5	Feb-95	129	502	3	0	505	1.514	0.00042	0.00234	0.01315
481109	6.5	May-95	132	571	0	0	571	1.558	0.00043	0.00241	0.01354
481109	6.5	Aug-96	147	425	0	0	425	1.79	0.00049	0.00274	0.01548
481169	1.1	Feb-90	211					160	0.0589	0.3564	2.174
481169	1.1	Mar-90	212					160.9	0.05926	0.3586	2.187
481169	1.1	Sep-90	218					163.8	0.06057	0.3659	2.228
481169	1.1	Jan-91	222	0	0	0	0	169.6	0.06243	0.3778	2.304
481169	1.1	Mar-91	224					171.9	0.06326	0.3829	2.335
481169	1.1	Jun-91	227	0	0	0	0	173.4	0.06394	0.3867	2.357
481169	1.1	Jan-92	234					180.8	0.06649	0.4025	2.455

Table D-2 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using Shell Oil Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})			
				Low	Medium	High	Total	1.0,1.1	1.1,0.9	1.1,1.0	1.1,1.1
481169	1.1	Feb-93	247	0	0	0	0	193.5	0.07104	0.4303	2.626
481169	1.1	Aug-93	253	0	0	0	0	196.7	0.0725	0.4386	2.673
481169	1.1	Mar-95	272	7	0	0	7	217.2	0.07969	0.4829	2.948
481169	1.1	Jul-95	276	0	0	0	0	219.2	0.08063	0.4881	2.977
481169	1.1	Jul-97	300	0	0	0	0	242.9	0.08921	0.5403	3.297
481174	4.7	Oct-90	186					0.0409	5E-06	3.3E-05	0.00022
481174	4.7	Feb-91	190					0.04132	5E-06	3.3E-05	0.00022
481174	4.7	Apr-91	192	201	0	0	201	0.0417	5E-06	3.3E-05	0.00022
481174	4.7	Mar-92	203	204	0	0	204	0.0441	5.3E-06	3.5E-05	0.00023
481174	4.7	Feb-93	214	138	0	0	138	0.04645	5.6E-06	3.7E-05	0.00025
481174	4.7	Mar-93	215	185	0	0	185	0.04662	5.6E-06	3.7E-05	0.00025
481174	4.7	Feb-95	238	220	10	0	229	0.05152	6.2E-06	4.1E-05	0.00027
481174	4.7	Mar-95	239	179	0	0	179	0.05168	6.2E-06	4.1E-05	0.00027
481174	4.7	Jan-96	249	160	0	0	160	0.05381	6.5E-06	4.3E-05	0.00028
481174	4.7	Apr-97	264	0	0	0	0	0.0569	6.8E-06	4.5E-05	0.0003
481174	4.7	Mar-98	275	49	0	0	49	0.05914	7.1E-06	4.7E-05	0.00031
481178	8.5	Feb-91	32					3.7E-05	6.1E-09	3.4E-08	1.9E-07
481178	8.5	May-91	33	48	0	0	48	3.7E-05	6.1E-09	3.4E-08	1.9E-07
481178	8.5	Feb-93	56	44	0	0	44	6.7E-05	1.1E-08	6.1E-08	3.4E-07
481178	8.5	Jul-93	61	94	0	0	94	7.4E-05	1.2E-08	6.6E-08	3.7E-07
481178	8.5	Feb-95	80	92	0	0	92	9.8E-05	1.5E-08	8.7E-08	4.9E-07
481178	8.5	Mar-95	81	57	0	0	57	9.8E-05	1.5E-08	8.7E-08	4.9E-07
481183	5.7	Sep-90	188	0	0	0	0	0.1275	2.9E-05	0.00018	0.00116
481183	5.7	Mar-91	194	0	0	0	0	0.1306	3E-05	0.00019	0.00118
481183	5.7	Oct-91	201	4	0	0	4	0.1471	3.4E-05	0.00021	0.00133
481183	5.7	Nov-91	202	11	0	0	11	0.1473	3.4E-05	0.00021	0.00133
481183	5.7	Jan-93	216	19	0	0	19	0.1712	3.9E-05	0.00025	0.00155
481183	5.7	Jul-93	222	3	0	0	3	0.184	4.2E-05	0.00026	0.00167
481183	5.7	Apr-94	231	3	0	0	3	0.1977	4.5E-05	0.00028	0.00179
483749	1.8	Oct-90	116	0	0	0	0	0.9297	0.00025	0.00159	0.01013
483749	1.8	Apr-91	122	0	0	0	0	0.9489	0.00025	0.00161	0.01029
483749	1.8	Aug-91	126	0	0	0	0	0.9689	0.00026	0.00164	0.01047
483749	1.8	Mar-92	133					0.9921	0.00026	0.00167	0.01066
483749	1.8	Feb-93	144	0	0	0	0	1.036	0.00027	0.00173	0.01104
483749	1.8	Mar-93	145	0	0	0	0	1.039	0.00027	0.00173	0.01107
483749	1.8	Feb-95	168					1.127	0.00029	0.00184	0.01183
483749	1.8	Mar-95	169	0	0	0	0	1.13	0.00029	0.00185	0.01185
483749	1.8	Mar-97	193	2	0	0	2	1.223	0.00031	0.00197	0.01266
489005	1.2	Oct-90	50	169	0	0	169	655.2	0.3471	2.107	12.88
489005	1.2	Mar-91	55	215	0	0	215	737.4	0.3822	2.336	14.38
489005	1.2	Aug-91	60	223	0	0	223	794.6	0.4164	2.536	15.55
489005	1.2	Feb-93	78	106	0	0	106	1060	0.5467	3.346	20.61
489005	1.2	Apr-93	80	240	0	0	240	1093	0.5632	3.447	21.24
489005	1.2	Feb-95	102	169	0	0	169	1390	0.7122	4.365	26.93
489005	1.2	Feb-96	114	274	0	0	274	1551	0.7926	4.861	30.01
489005	1.2	Jul-96	119	253	0	0	253	1616	0.8282	5.075	31.29
489005	1.2	Jul-97	131	325	0	0	325	1789	0.9158	5.614	34.63
489005	1.2	Jul-98	143	278	0	0	278	1960	1.001	6.142	37.91

Table D-2 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using Shell Oil Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})			
				Low	Medium	High	Total	1.0,1.1	1.1,0.9	1.1,1.0	1.1,1.1
501002	8.5	Aug-89	58					0.9474	0.00014	0.00107	0.00838
501002	8.5	Aug-90	70					1.62	0.00024	0.00188	0.01472
501002	8.5	May-94	115	2	0	0	2	2.545	0.00037	0.00294	0.02304
501002	8.5	Aug-94	118	0	0	0	0	2.545	0.00037	0.00294	0.02304
501002	8.5	Apr-95	126	8	0	0	8	2.58	0.00038	0.00297	0.02328
501002	8.5	Oct-96	144	16	0	0	16	2.807	0.00041	0.00322	0.02522
501002	8.5	May-97	151	66	125	0	191	4.277	0.00066	0.00521	0.04087
501002	8.5	Oct-97	156	10	5	0	14	4.277	0.00066	0.00521	0.04087
501002	8.5	Jun-98	164	10	26	0	36	4.312	0.00067	0.00524	0.04112
501004	8	Apr-93	102					8.601	0.0013	0.01083	0.0904
501004	8	Oct-95	132					8.708	0.00131	0.01092	0.09112
501004	8	Nov-97	157					14.54	0.00218	0.01823	0.1522
511002	5.7	Apr-89	115					1.15	0.00013	0.00111	0.00948
511023	10.1	Oct-89	107					0.06425	6.3E-06	5E-05	0.00039
511023	10.1	Mar-91	124					0.114	1.1E-05	8.7E-05	0.00069
511023	10.1	May-92	138	0	0	0	0	0.1143	1.1E-05	8.8E-05	0.00069
511023	10.1	Oct-92	143	21	0	0	21	0.1146	1.1E-05	8.8E-05	0.00069
511023	10.1	Dec-93	157	0	0	0	0	0.1459	1.4E-05	0.00011	0.00088
511023	10.1	Sep-95	178	105	0	0	105	0.1465	1.4E-05	0.00011	0.00089
511023	10.1	Feb-96	183	167	0	0	167	0.1465	1.4E-05	0.00011	0.00089
511023	10.1	Mar-97	196	4	0	0	4	0.1814	1.8E-05	0.00014	0.0011
512021	7.5	Oct-89	54					0.1099	1.2E-05	9.9E-05	0.0008
512021	7.5	Mar-91	71					0.212	2.4E-05	0.0002	0.00158
512021	7.5	Oct-92	90	21	0	0	21	0.2258	2.6E-05	0.00021	0.00166
531008	3.4	Jul-91	153	6	0	0	6	0.0893	1.1E-05	8.3E-05	0.00061
531008	3.4	Jun-93	176	66	0	0	67	0.09943	1.2E-05	9.1E-05	0.00068
531008	3.4	Jun-94	188	8	5	8	21	0.1091	1.4E-05	0.0001	0.00074
561007	2.8	Jul-90	121					1.043	0.00016	0.00129	0.0102
561007	2.8	May-91	131	0	0	0	0	1.17	0.00018	0.00145	0.01144
561007	2.8	Aug-91	134					1.171	0.00018	0.00145	0.01144
561007	2.8	Aug-93	158	13	0	0	13	1.396	0.00022	0.00175	0.01383
561007	2.8	Oct-93	160	26	0	0	26	1.399	0.00022	0.00175	0.01385
561007	2.8	Dec-93	162	4	0	0	4	1.513	0.00024	0.0019	0.01499
561007	2.8	Mar-94	165	6	0	0	6	1.522	0.00024	0.00191	0.01506
561007	2.8	Apr-94	166	0	0	0	0	1.523	0.00024	0.00191	0.01506
561007	2.8	Aug-94	170	6	0	0	6	1.523	0.00024	0.00191	0.01507
561007	2.8	Feb-95	176	7	0	0	7	1.735	0.00028	0.0022	0.01736
561007	2.8	May-95	179	0	0	0	0	1.735	0.00028	0.0022	0.01736
561007	2.8	Sep-95	183	0	0	0	0	1.737	0.00028	0.0022	0.01738
561007	2.8	Jun-96	192	5	0	0	5	1.753	0.00028	0.00222	0.0175
561007	2.8	Oct-96	196	0	0	0	0	1.757	0.00028	0.00222	0.01753
561007	2.8	Nov-96	197	2	0	0	2	1.766	0.00028	0.00223	0.0176
561007	2.8	Mar-97	201	0	0	0	0	1.87	0.0003	0.00236	0.01861
561007	2.8	Aug-97	206	3	0	0	3	1.871	0.0003	0.00236	0.01862
561007	2.8	Sep-97	207	0	0	0	0	1.871	0.0003	0.00236	0.01862

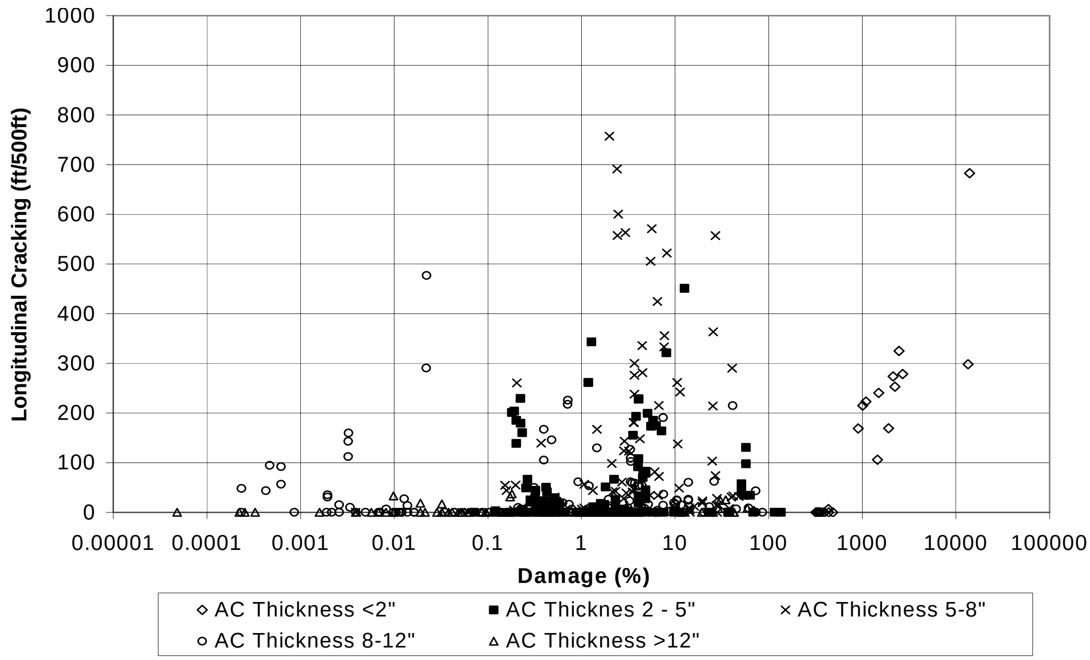

Figure D-1 Longitudinal Cracking vs. Predicted Top-Down Damage (AC 1,0.9,0.9)

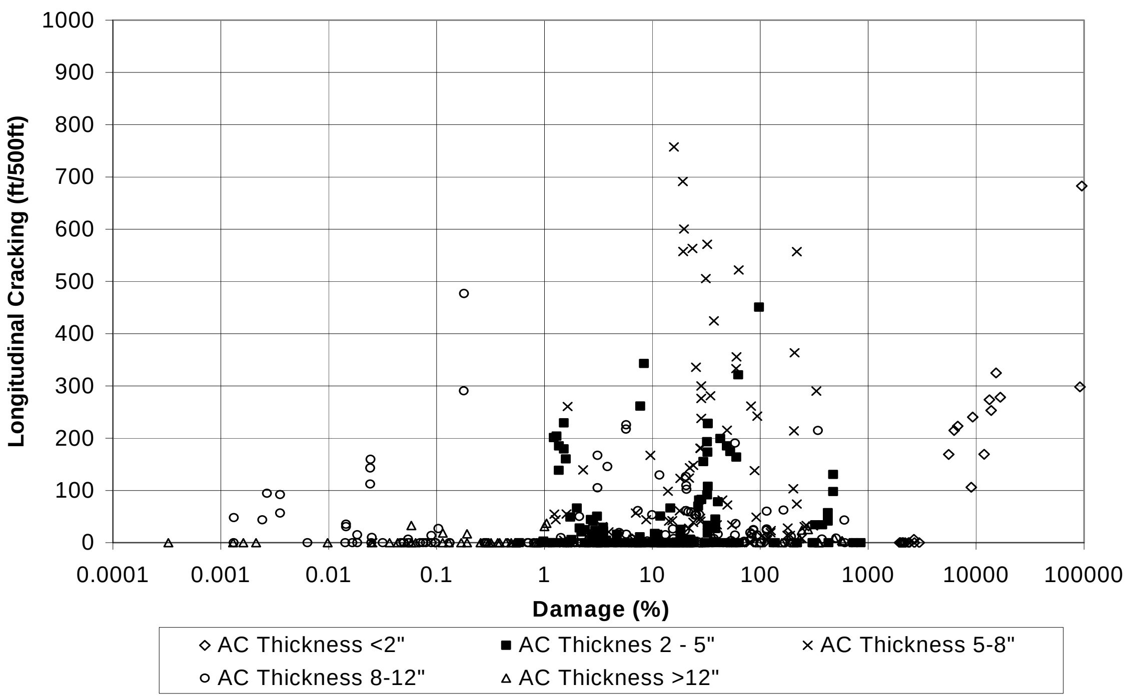

Figure D-2 Longitudinal Cracking vs. Predicted Top-Down Damage (AC 1,0.9,1.0)

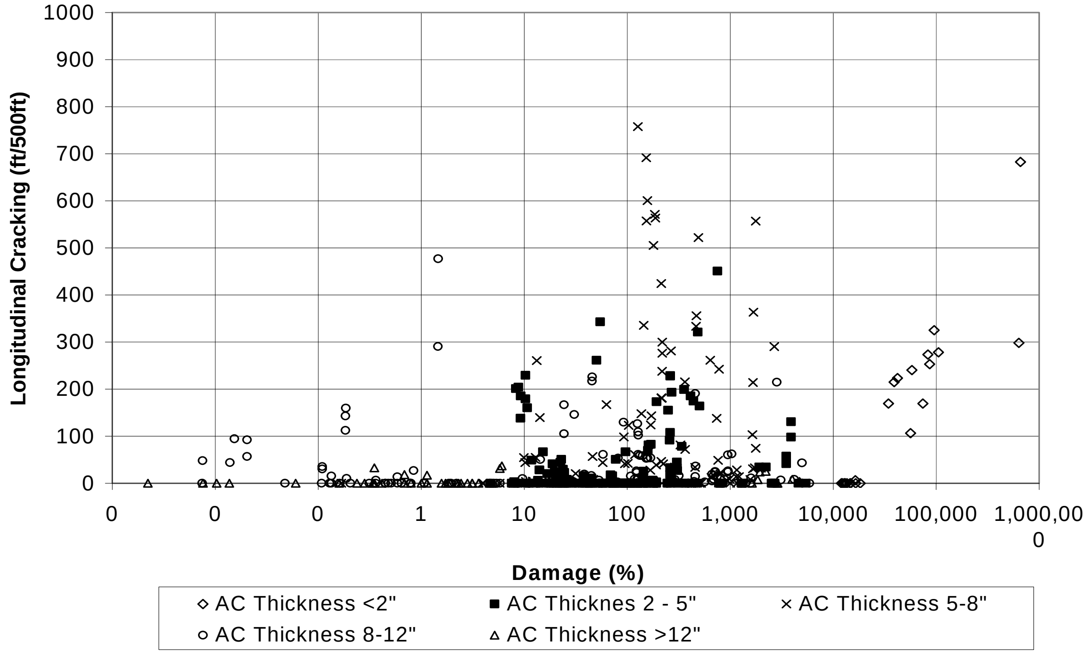

Figure D-3 Longitudinal Cracking vs. Predicted Top-Down Damage (AC 1,0.9,1.1)

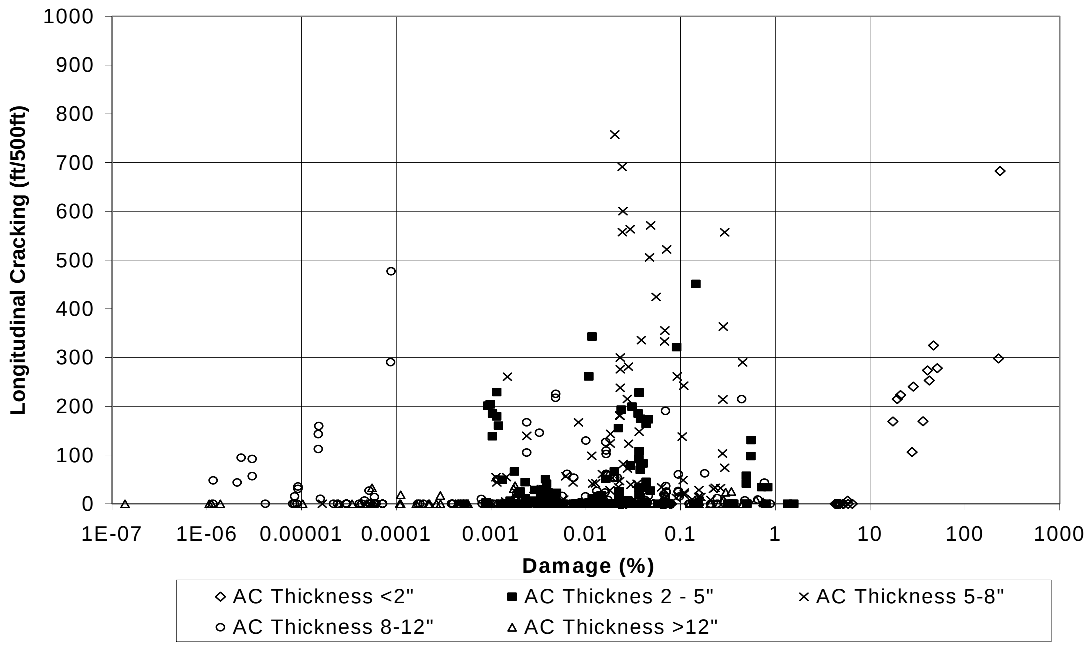

Figure D-4 Longitudinal Cracking vs. Predicted Top-Down Damage (AC 1,1.0,0.9)

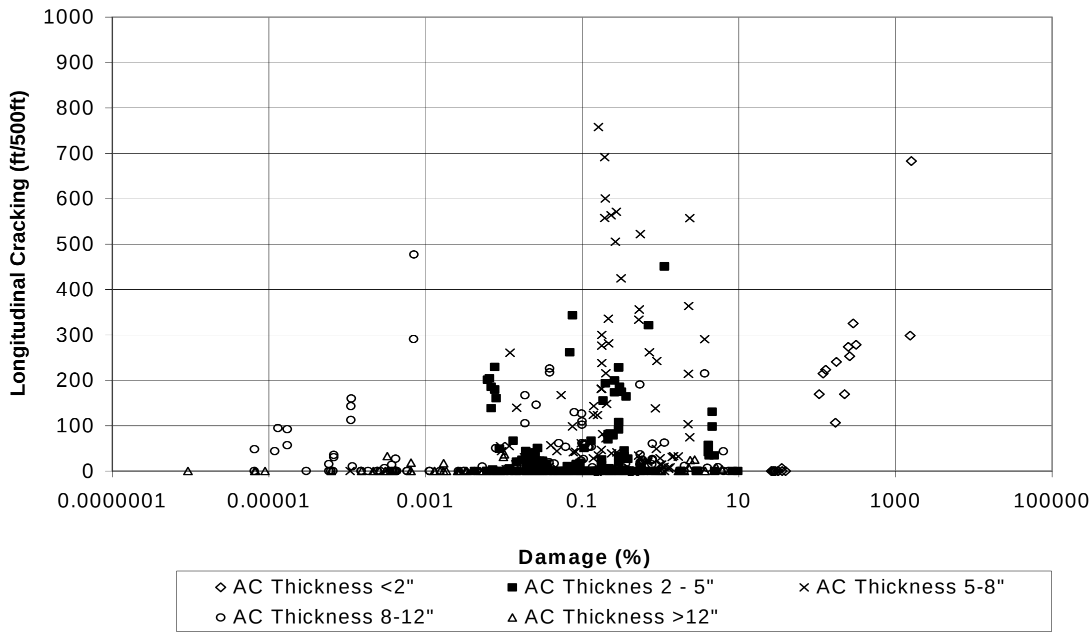

Figure D-5 Longitudinal Cracking vs. Predicted Top-Down Damage (AC 1,1.0,1.0)

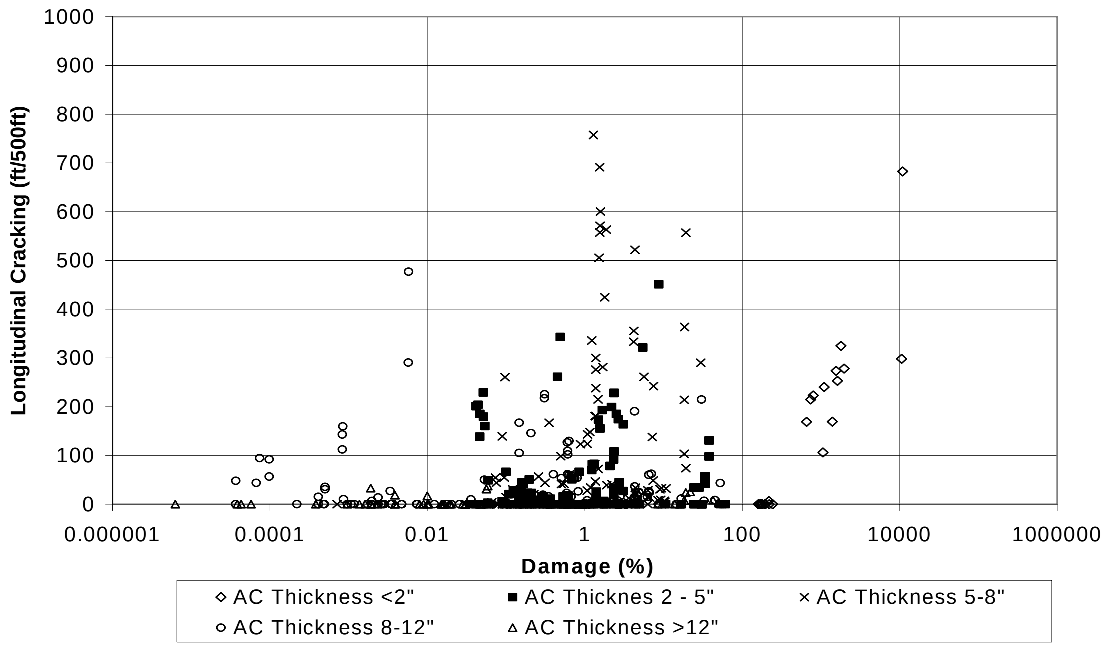

Figure D-6 Longitudinal Cracking vs. Predicted Top-Down Damage (AC 1,1.0,1.1)

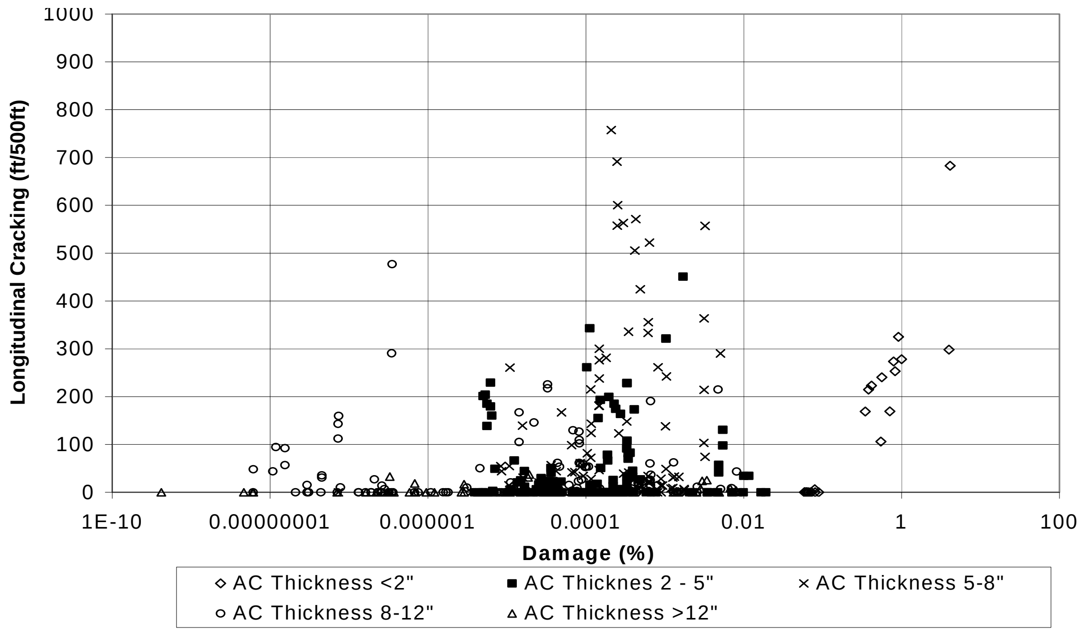

Figure D-7 Longitudinal Cracking vs. Predicted Top-Down Damage (AC 1,1.1,0.9)

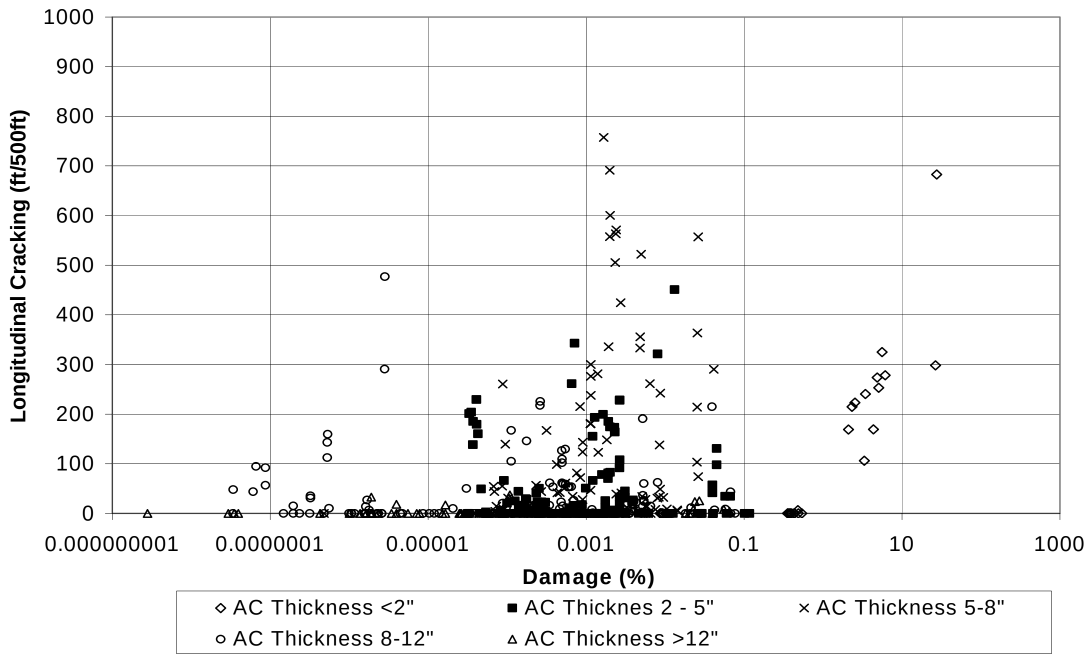

Figure D-8 Longitudinal Cracking vs. Predicted Top-Down Damage (AC 1,1.1,1.0)

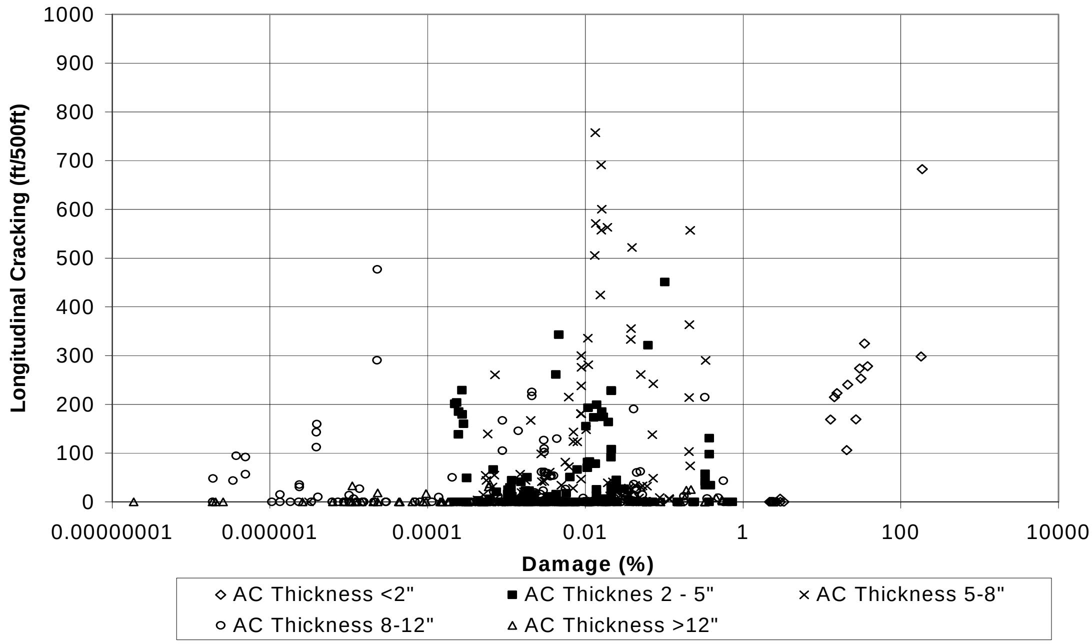

Figure D-9 Longitudinal Cracking vs. Predicted Top-Down Damage (AC 1,1.1,1.1)

ANNEX E

Top-Down Longitudinal Fatigue Cracking MS-1 Model Calibration

Table E-1 Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS1 Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Medium	High	Total	0.8,0.8	0.8,1.5	0.8,2.5	1.0,0.8	1.0,1.0	1.0,1.5
11001	3.2	Sep-91	132	0	0	0	0	1900	6481000	9.7E+11	1.95	18.98	6048
11001	3.2	Apr-92	139	16	0	0	16	1991	6923000	1.1E+12	2.027	19.83	6410
11001	3.2	Jul-92	142	14	0	0	14	2050	7063000	1.1E+12	2.097	20.46	6567
11001	3.2	Jan-93	148	30	0	0	30	2141	7399000	1.1E+12	2.185	21.35	6869
11019	6.7	May-89	32					133	496500	7.8E+10	0.1046	1.064	366.9
11019	6.7	Apr-90	43					176.9	662900	1E+11	0.139	1.414	488.5
11019	6.7	Jan-91	52					213.6	791600	1.2E+11	0.1687	1.711	586.1
11019	6.7	Jun-91	57	4	0	0	4	234	870700	1.4E+11	0.1845	1.873	643.8
11019	6.7	Mar-92						265.6	999100	1.6E+11	0.2083	2.121	733.8
11019	6.7	Mar-93	78	139	0	0	139	313.4	1193000	1.9E+11	0.245	2.502	872.8
11019	6.7	Jul-95	106	0	0	0		498.3	1877000	3E+11	0.4088	4.168	1444
11019	6.7	Jan-98	136	0	0	0		635.9	2418000	3.9E+11	0.5213	5.328	1857
14126	13.1	Jun-89	15	0	0	0	0	29.28	47640	2.2E+09	0.05181	0.4184	78.45
14126	13.1	Mar-91	36	0	0	0	0	55.15	93340	4.5E+09	0.09163	0.748	144.2
14126	13.1	Mar-93	60	0	0	0	0	75.5	132700	6.9E+09	0.1187	0.9785	193.2
14126	13.1	Apr-94	73	0	0	0	0	87.8	156600	8.2E+09	0.1347	1.115	222.6
14126	13.1	Dec-95	93	0	0	0	0	109.1	197800	1.1E+10	0.1628	1.354	273.6
14126	13.1	Dec-97	117	0	0	0	0	130.3	240100	1.3E+10	0.1892	1.581	323.4
21001	3	May-90	83	0	0	0	0	127.6	725800	1.9E+11	0.1123	1.284	596.5
21001	3	Aug-91	98	0	0	0	0	160.3	896100	2.3E+11	0.1432	1.63	747.2
21001	3	Aug-93	122	27	0	0	27	196.6	1113000	2.9E+11	0.175	2.002	929.3
21001	3	Jun-95	144	0	0	0	0	239.2	1382000	3.7E+11	0.212	2.447	1158
21001	3	Aug-97	170	0	0	0	0	287	1646000	4.4E+11	0.256	2.946	1384
21001	3	Aug-98	182	0	0	0	0	307.1	1772000	4.8E+11	0.2737	3.159	1495
21002	3.3	May-90	68	0	0	0	0	29.21	159100	4.2E+10	0.02423	0.2664	115.2
21002	3.3	Aug-91	83	6	0	0	6	37.24	197400	5.1E+10	0.03212	0.3488	146.9
21002	3.3	Aug-93	107	0	0	0	0	48.29	256400	6.7E+10	0.04168	0.4521	190.1
21002	3.3	Jun-95	129	0	0	0	0	60.59	325800	8.7E+10	0.05295	0.5771	245.9
21002	3.3	Aug-97	155	0	0	0	0	71.04	382600	1E+11	0.06127	0.6694	286.2
21002	3.3	May-98	164	0	0	0	0	75.99	417200	1.1E+11	0.06507	0.7169	312.6
40113	4.5	Feb-95	19	0	0	0	0	564.8	2661000	6.4E+11	0.413	4.35	1734
40113	4.5	Mar-95	20	11	0	0	11	591.8	2819000	6.9E+11	0.4295	4.544	1828
40113	4.5	Aug-95	25	0	0	0	0	762	3436000	7.9E+11	0.5625	5.867	2269
40113	4.5	Nov-95	28	0	0	0	0	855.1	3863000	8.8E+11	0.625	6.541	2541
40113	4.5	Feb-96	31	0	0	0	0	942.7	4461000	1.1E+12	0.6764	7.177	2888
40113	4.5	Apr-96	33	0	0	0	0	1002	4776000	1.1E+12	0.7141	7.603	3081
40113	4.5	Jul-96	36	0	0	0	0	1125	5147000	1.2E+12	0.8183	8.599	3373
40113	4.5	Aug-96	37	0	0	0	0	1171	5282000	1.2E+12	0.8576	8.973	3482
40113	4.5	Jan-98	54	53	17	0	70	1776	8426000	2E+12	1.263	13.45	5440
40113	4.5	Apr-98	57	17	65	0	82	1880	9106000	2.2E+12	1.326	14.21	5838
40113	4.5	Jun-98	59	24	59	0	83	1957	9425000	2.3E+12	1.38	14.77	6047

Table E-1 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS-1 Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Medium	High	Total	0.8,0.8	0.8,1.5	0.8,2.5	1.0,0.8	1.0,1.0	1.0,1.5
40113	4.5	Oct-98	63	0	173	0	173	2146	1E+07	2.4E+12	1.528	16.25	6541
40114	6.8	Feb-95	19	0	0	0	0	591.6	2184000	3.7E+11	0.4941	4.921	1633
40114	6.8	Mar-95	20	31	0	0	31	612.9	2289000	3.9E+11	0.5082	5.076	1697
40114	6.8	Aug-95	25	0	0	0	0	872.9	3147000	5.1E+11	0.7407	7.361	2416
40114	6.8	Nov-95	28	0	0	0	0	1003	3650000	5.9E+11	0.847	8.449	2797
40114	6.8	Feb-96	31	7	0	0	7	1033	3828000	6.4E+11	0.8623	8.628	2883
40114	6.8	Apr-96	33	9	0	0	9	1096	4097000	6.9E+11	0.91	9.129	3069
40114	6.8	Jul-96	36	44	0	0	44	1298	4717000	7.6E+11	1.098	10.95	3619
40114	6.8	Aug-96	37	0	0	0		1373	4948000	7.9E+11	1.168	11.63	3825
40114	6.8	Jan-98	54	33	40	26	98	1999	7329000	1.2E+12	1.685	16.86	5610
40114	6.8	Apr-98	57	0	41	0	41	2051	7587000	1.3E+12	1.719	17.23	5759
40114	6.8	Jun-98	59	0	42	0	42	2170	8026000	1.3E+12	1.82	18.25	6104
40114	6.8	Oct-98	63	38	23	0	61	2458	9008000	1.5E+12	2.074	20.77	6918
40115	15.1	Feb-95	19	0	0	0	0	372.8	677400	3.6E+10	0.5021	4.175	845.4
40115	15.1	Mar-95	20	33	0	0	33	374.8	683100	3.6E+10	0.5033	4.186	848.8
40115	15.1	Jan-98	54	0	0	0	0	1039	2072000	1.2E+11	1.241	10.6	2301
40116	16.2	Feb-95	19	0	0	0	0	106	223400	1.4E+10	0.1152	1.001	226.1
40116	16.2	Mar-95	20	18	0	0	18	106.5	225300	1.5E+10	0.1155	1.004	227
40116	16.2	Jan-98	54	0	0	0	0	280.6	649100	4.7E+10	0.2662	2.376	574.1
40117	11.8	Feb-95	19	0	0	0	0	97.64	210600	1.5E+10	0.09658	0.8389	189.3
40117	11.8	Mar-95	20	14	0	0	14	97.99	211900	1.5E+10	0.09669	0.8401	189.7
40117	11.8	Jan-98	54	0	0	0	0	264.7	631300	5E+10	0.2245	2.005	486.1
40118	11.7	Feb-95	19	0	0	0	0	46.63	103700	7.4E+09	0.03416	0.2996	69.67
40118	11.7	Mar-95	20	15	0	0	15	46.67	103800	7.4E+09	0.03417	0.2997	69.7
40118	11.7	Jan-98	54	0	0	0	0	129.1	319000	2.6E+10	0.08078	0.7312	184.4
41007	6.5	Sep-91	162	0	0	0	0	423.7	1785000	3.6E+11	0.2531	2.637	982.2
41007	6.5	Feb-93	163	57	0	0	57	426.8	1803000	3.6E+11	0.2547	2.656	991
41007	6.5	Sep-94	198	167	0	0	167	575.4	2453000	5E+11	0.3412	3.571	1343
41024	10.8	Nov-89	149					3079	8327000	8.1E+11	2.247	20.83	5627
41024	10.8	Aug-90	158					3403	9214000	8.9E+11	2.483	23.04	6233
41024	10.8	Oct-92	184	0	0	0	0	4269	1.2E+07	1.1E+12	3.104	28.87	7850
41024	10.8	Mar-95	213	9	0	0	9	5119	1.4E+07	1.4E+12	3.688	34.39	9414
41024	10.8	Jul-95	217	23	0	0	23	5440	1.5E+07	1.5E+12	3.921	36.57	10010
41024	10.8	Aug-95	218	127	0	0	127	5566	1.5E+07	1.5E+12	4.014	37.45	10260
41024	10.8	Nov-95	221	109	0	0	109	5661	1.6E+07	1.5E+12	4.073	38.02	10430
41024	10.8	Feb-96	224	61	0	0	61	5661	1.6E+07	1.5E+12	4.073	38.02	10430
41024	10.8	Apr-96	226	79	0	23	102	5672	1.6E+07	1.5E+12	4.079	38.07	10440
41024	10.8	Jun-96	228	59	0	0	59	5781	1.6E+07	1.6E+12	4.151	38.75	10640
41024	10.8	Aug-96	230	59	0	0	59	6102	1.7E+07	1.6E+12	4.402	41.08	11260
41024	10.8	Apr-98	250	49	0	4	53	6764	1.9E+07	1.8E+12	4.865	45.45	12490
41024	10.8	Jun-98	252	49	0	4	53	6915	1.9E+07	1.9E+12	4.97	46.44	12760
41024	10.8	Oct-98	256	50	0	4	54	7244	2E+07	2E+12	5.185	48.51	13380
81029	4.2	Oct-91	233	0	25	0	25	113.2	618000	1.7E+11	0.09184	1.031	474
81029	4.2	Jul-94	266	44	0	0	44	130.1	716200	1.9E+11	0.1049	1.181	547

Table E-1 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS-1 Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Medium	High	Total	0.8,0.8	0.8,1.5	0.8,2.5	1.0,0.8	1.0,1.0	1.0,1.5
81029	4.2	Sep-95	280	11	0	0	11	137.2	754400	2E+11	0.1103	1.242	574.9
81053	4.6	Oct-89	60					74.34	390100	1E+11	0.07007	0.7724	335.3
81053	4.6	Jul-90	69					81.96	442900	1.2E+11	0.07532	0.8372	371.3
81053	4.6	Apr-93	102	92	0	0	92	144.2	791600	2.2E+11	0.1315	1.469	660.1
81053	4.6	Nov-93	109	18	0	0	18	183	951800	2.5E+11	0.1758	1.929	828.7
81053	4.6	Dec-93	110	33	0	0	33	184.1	960600	2.5E+11	0.1765	1.938	834.2
81053	4.6	Oct-94	120	108	0	0	108	236.1	1210000	3.1E+11	0.2323	2.538	1078
81053	4.6	Feb-95	124	228	0	0	228	247.9	1301000	3.5E+11	0.242	2.662	1152
81053	4.6	May-95	127	229	0	0	229	250.5	1318000	3.5E+11	0.2435	2.681	1162
81053	4.6	May-96	139	0	0	0		261.5	1391000	3.8E+11	0.2504	2.764	1206
81053	4.6	Oct-96	144	0	0	0		264.8	1405000	3.8E+11	0.2524	2.786	1215
81053	4.6	Nov-96	145	33	0	0		265.5	1411000	3.8E+11	0.2529	2.791	1218
81053	4.6	Mar-97	149	45	0	0		277.2	1499000	4.1E+11	0.2615	2.902	1283
91803	7.2	Jul-89	49					19.33	84070	1.7E+10	0.01452	0.1519	57.83
91803	7.2	Sep-90	63					25.93	110800	2.2E+10	0.0194	0.2022	75.89
91803	7.2	Aug-91	74	7	0	0	7	31.84	137200	2.8E+10	0.02371	0.2473	93.2
91803	7.2	Sep-92	87	5	0	0	5	40.59	180500	3.8E+10	0.03014	0.3185	123.9
91803	7.2	May-94	107	103	0	0	103	50.92	228300	4.8E+10	0.03725	0.3938	153.3
91803	7.2	May-95	119	207	7	0	214	59.97	269800	5.7E+10	0.04365	0.4621	180.3
91803	7.2	Oct-96	136	364	0	0	364	75.49	330900	6.8E+10	0.05537	0.5818	222.4
91803	7.2	May-97	143	557	0	0	557	79.92	358100	7.6E+10	0.05791	0.612	237.5
91803	7.2	Sep-97	147	74	0	0	74	85.7	378700	7.9E+10	0.06249	0.6582	253
91803	7.2	Jun-98	156	279	11	0	290	95.47	434100	9.3E+10	0.06955	0.7397	291.8
120103	12	Dec-96	14	0	0	0	0	0.4428	1448	1.7E+08	0.00017	0.00171	0.533
120104	18	Dec-96	14	0	0	0	0	1.116	3323	3.3E+08	0.0007	0.0068	2.004
120105	7.9	Dec-96	14	0	0	0	0	4.519	17870	2.7E+09	0.0024	0.02523	9.198
120106	15	Dec-96	14	0	0	0	0	0.7496	2271	2.3E+08	0.00043	0.00414	1.24
123995	5	Apr-92	197	34	0	0	34	88380	3E+08	3.8E+13	61.57	617	201200
123995	5	Mar-94	220	82	0	0	82	101200	3.5E+08	4.4E+13	70.63	707.7	230500
123995	5	Jan-96	242	215	0	0	215	112600	3.9E+08	4.9E+13	78.51	787	256700
123995	5	Jan-96	243	72	0	0	72	113000	3.9E+08	4.9E+13	78.69	789	257500
123997	3.1	Aug-90	195					3504	1.1E+07	1.2E+12	5.151	48.8	13980
123997	3.1	Oct-91	209					3855	1.2E+07	1.4E+12	5.634	53.48	15390
123997	3.1	Mar-93	226					4227	1.3E+07	1.6E+12	6.122	58.24	16870
123997	3.1	Mar-94	238					4612	1.4E+07	1.7E+12	6.683	63.59	18430
124105	2.3	Apr-89	53	0	0	0	0	8544	2.6E+07	3E+12	18.76	178.5	51830
124105	2.3	Oct-91	83	0	0	0	0	13540	4.1E+07	4.8E+12	29.74	283.9	82810
124105	2.3	Mar-93	100	0	0	0	0	15590	4.9E+07	5.8E+12	33.75	323.6	95470
124106	8.2	Apr-89	21					289.6	949600	1.1E+11	0.1534	1.523	485.3
124106	8.2	Feb-91	43					566	1931000	2.4E+11	0.2938	2.951	966.8
124106	8.2	Jul-91	48	0	0	0	0	633.4	2163000	2.7E+11	0.3287	3.303	1083
124106	8.2	Mar-94	80	10	0	0	10	1017	3587000	4.7E+11	0.5192	5.265	1766
124106	8.2	Jan-97	114	50	0	0	50	1423	5090000	6.8E+11	0.7208	7.341	2487
124107	2.7	Dec-89	75	0	0	0	0	390.9	1351000	1.8E+11	0.6012	5.993	1928
124107	2.7	Feb-91	89	261	0	0	261	467.4	1638000	2.2E+11	0.7113	7.115	2309

Table E-1 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS-1 Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Medium	High	Total	0.8,0.8	0.8,1.5	0.8,2.5	1.0,0.8	1.0,1.0	1.0,1.5
124107	2.7	Jul-91	94	343	0	0	343	503.9	1762000	2.4E+11	0.7682	7.683	2492
124107	2.7	Mar-93	114	18	0	0	18	624.3	2215000	3E+11	0.9424	9.453	3092
124107	2.7	Mar-94	126	37	13	0	51	709.3	2523000	3.5E+11	1.069	10.73	3516
124107	2.7	Jan-96	148	67	0	0	67	866.2	3115000	4.3E+11	1.291	13.01	4297
124107	2.7	Mar-97	162	0	0	0		973	3520000	5E+11	1.443	14.56	4829
124108	9.9	Apr-89	35	0	0	0	0	12.69	33830	3.7E+09	0.01203	0.1078	27.17
124108	9.9	Jan-91	56	0	0	0	0	20.72	55500	6.1E+09	0.02032	0.1818	45.64
124108	9.9	Oct-91	65	0	0	0	0	24.08	65410	7.2E+09	0.023	0.207	52.75
124108	9.9	Mar-94	94	7	0	0	7	34.46	96310	1.1E+10	0.0327	0.2963	76.87
124108	9.9	Aug-94	99	0	0	0	0	36.74	103100	1.2E+10	0.03447	0.3132	81.75
124108	9.9	Jan-96	116	0	0	0	0	41.69	119300	1.4E+10	0.03817	0.3488	92.37
124135	1.4	Dec-89	227	99	199	0	298	250600	9.6E+08	1.5E+14	856.8	8764	3046000
124135	1.4	Jan-91	240	412	271	0	683	263100	1E+09	1.6E+14	897.1	9186	3200000
131031	11.1	Apr-91	119	0	0	0	0	44.99	127700	1.3E+10	0.03012	0.2822	78.64
131031	11.1	Jul-92	134	0	0	0	0	58.68	166800	1.8E+10	0.03928	0.3686	103
131031	11.1	Jan-93	140	0	0	0	0	63.18	179600	1.9E+10	0.04238	0.3976	111.1
131031	11.1	Apr-94	155	0	0	0	0	74.64	213100	2.3E+10	0.04989	0.4687	131.3
131031	11.1	Oct-94	161	0	0	0	0	83.35	239100	2.5E+10	0.05549	0.5222	146.9
131031	11.1	Aug-95	171	0	0	0	0	94.69	271100	2.9E+10	0.06322	0.595	167.3
131031	11.1	Jan-96	176	4	0	0	4	97.99	281900	3E+10	0.06521	0.6142	173.2
131031	11.1	Apr-96	179	23	0	0	23	98.44	283800	3.1E+10	0.06539	0.6161	173.8
134111	8.7	Mar-89	101	27	0	0	27	34.3	101300	1.1E+10	0.02841	0.2696	77.27
134111	8.7	Mar-91	125	291	0	0	291	50.98	152700	1.7E+10	0.04178	0.3983	115.4
134111	8.7	Feb-92	136	477	0	0	477	59.21	178000	2E+10	0.04838	0.462	134.3
134112	15.9	May-89	144	0	0	0	0	146.3	354700	2.9E+10	0.1825	1.634	403.1
134112	15.9	Feb-91	165	17	0	0	17	181.9	446000	3.7E+10	0.2255	2.028	504.9
134112	15.9	Apr-91	167	0	0	0	0	182.3	447400	3.7E+10	0.2258	2.031	505.8
134112	15.9	Feb-94	201	0	0	0	0	245.7	611500	5.2E+10	0.3009	2.719	684.6
134112	15.9	Oct-94	209	0	0	0	0	263.6	659300	5.6E+10	0.3202	2.898	732.7
134112	15.9	Jan-96	224	0	0	0	0	292.8	731500	6.2E+10	0.3572	3.235	818.3
134112	15.9	Feb-97	237	0	0	0	0	319.8	800400	6.7E+10	0.3897	3.532	894.9
134112	15.9	Apr-98	251	0	0	0	0	349.4	876600	7.4E+10	0.4246	3.853	978.1
134113	15.2	May-89	144	0	0	0	0	382.8	862300	6.4E+10	0.5006	4.387	1024
134113	15.2	Feb-91	165	0	0	0	0	456.1	1041000	7.9E+10	0.5906	5.199	1226
134113	15.2	Apr-91	167	0	0	0	0	457.1	1044000	7.9E+10	0.5912	5.205	1228
134113	15.2	Feb-94	201	0	0	0	0	589.3	1367000	1E+11	0.7538	6.671	1593
134113	15.2	Oct-94	209	0	0	0	0	627.7	1461000	1.1E+11	0.7978	7.072	1695
134113	15.2	Jan-96	224	0	0	0	0	684.5	1594000	1.2E+11	0.8716	7.734	1857
134113	15.2	Feb-97	237	31	0	0	31	738.4	1724000	1.3E+11	0.9389	8.34	2007
134113	15.2	Apr-98	251	37	0	0	37	798.8	1869000	1.4E+11	1.015	9.021	2175
161001	3.7	Jul-89	192	155	0	0	155	8142	4.4E+07	1.1E+13	8.538	96.5	43980
161001	3.7	Aug-90	205	193	0	0	193	9320	5E+07	1.3E+13	9.844	111	50340
161001	3.7	Jun-93	239	78	0	0	78	11730	6.4E+07	1.7E+13	12.3	139.3	63750
161001	3.7	Aug-94	253	199	0	0	199	12810	7E+07	1.8E+13	13.44	151.9	69250

Table E-1 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS-1 Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Medium	High	Total	0.8,0.8	0.8,1.5	0.8,2.5	1.0,0.8	1.0,1.0	1.0,1.5
161001	3.7	May-95	262	183	2	0	185	13770	7.6E+07	2E+13	14.4	163.4	75090
161001	3.7	Jul-97	288	67	63	44	175	16270	8.9E+07	2.3E+13	17.09	193.5	88410
161001	3.7	Sep-98	302	0	159	5	164	17260	9.4E+07	2.4E+13	18.05	204.5	93620
161009	10.4	Sep-89	180					34.65	130400	2.5E+10	0.02238	0.2209	74.75
161009	10.4	Jul-90	190					36.59	137400	2.7E+10	0.02343	0.2312	78.06
161009	10.4	Jul-92	214	0	0	0	0	45.07	171700	3.4E+10	0.02888	0.2863	98.09
161009	10.4	Oct-93	229	8	0	0	8	51.11	191500	3.7E+10	0.03279	0.3234	108.9
161009	10.4	Jun-96	261	1	0	0	1	60.69	229100	4.4E+10	0.03803	0.376	127
161009	10.4	Jul-97	274	0	0	0	0	69.94	268500	5.3E+10	0.04435	0.4408	151.8
161021	5.9	Sep-89	48					36.66	192900	5.3E+10	0.0244	0.2623	113.1
161021	5.9	Oct-90	61	0	0	0	0	48.09	257400	7.1E+10	0.03186	0.3455	151.4
161021	5.9	Aug-91	71	0	0	0	0	54.89	293900	8.1E+10	0.03594	0.3897	170.6
161021	5.9	Aug-93	95	0	0	0	0	74.93	405200	1.1E+11	0.04938	0.5379	237.9
161021	5.9	Sep-95	120	0	0	0	0	96.86	526600	1.5E+11	0.06338	0.6927	308
161021	5.9	Jun-96	129	5	0	0	5	102.8	563700	1.6E+11	0.06643	0.7287	326.3
161021	5.9	Jul-97	142	0	0	0	0	113	615700	1.7E+11	0.07302	0.798	354.6
169034	9.2	Jul-89	10					5.219	20030	3.9E+09	0.00306	0.02976	9.498
169034	9.2	Aug-90	23					16.37	57020	1E+10	0.01108	0.1048	31.13
169034	9.2	Jun-93	57	12	0	0	12	34.02	131500	2.7E+10	0.0211	0.206	67.3
169034	9.2	Aug-94	71	146	0	0	146	43.65	165100	3.2E+10	0.02705	0.2634	84.88
169034	9.2	May-95	80					46.24	179100	3.6E+10	0.02816	0.2759	90.46
169034	9.2	Jul-97	106	217	0	0	217	62.92	245000	5E+10	0.03815	0.3755	124.7
169034	9.2	Sep-98	120	156	52	18	226	71.04	276400	5.6E+10	0.04277	0.4211	139.7
201009	11.1	Aug-88	44	0	0	0	0	5.739	25500	6.9E+09	0.00385	0.03963	15.63
201009	11.1	May-89	53	11	0	0	11	6.657	31810	9.1E+09	0.0043	0.04514	18.68
201009	11.1	Dec-90	72	210	5	0	215	9.766	47580	1.4E+10	0.00631	0.06687	28.22
201009	11.1	Oct-91	82	6	1	0	7	10.86	50960	1.4E+10	0.007	0.07334	30.07
201009	11.1	Apr-93	100	9	0	0	9	12.54	60970	1.7E+10	0.00799	0.08486	35.88
201009	11.1	Apr-95	124	16	28	0	43	16.6	82180	2.4E+10	0.01053	0.1124	48.15
201009	11.1	Apr-96	136	0	0	0		17.33	84820	2.4E+10	0.01091	0.1162	49.34
201009	11.1	Jan-99	168	0	0	0		21.69	105300	3E+10	0.01347	0.1432	60.41
251003	6.6	Aug-89	180	758	0	0	758	73.37	368800	8.6E+10	0.06355	0.7041	303.2
251003	6.6	Sep-90	193	691	0	0	691	80.03	403800	9.4E+10	0.06919	0.7677	331.5
251003	6.6	Aug-91	204	556	1	0	557	85.6	432100	1E+11	0.07392	0.8202	354.2
251003	6.6	Sep-92	217	600	0	0	600	93.16	468400	1.1E+11	0.08059	0.8928	384.4
251003	6.6	Oct-95	254	563	0	0	563	115	582500	1.4E+11	0.09922	1.102	477.7
251003	6.6	Oct-96	266	39	0	0	39	122.2	618800	1.5E+11	0.1054	1.171	507.2
251003	6.6	Jun-98	286	32	9	0	41	135.1	687000	1.6E+11	0.1165	1.295	562.7
251004	9.6	Aug-89	178	0	0	0	0	29.77	105100	1.7E+10	0.02765	0.272	86.91
251004	9.6	Sep-90	191	19	0	0	19	33.04	116300	1.8E+10	0.03071	0.3019	96.2
251004	9.6	Aug-91	202	16	0	0	16	35.76	125100	1.9E+10	0.0333	0.3271	103.8
251004	9.6	Sep-92	215	0	0	0		40.05	139500	2.1E+10	0.03736	0.3666	116
251004	9.6	Oct-95	252	0	0	0		52.18	184500	2.9E+10	0.04833	0.4758	152
251004	9.6	Jun-97	272	3	0	0	3	58.44	205900	3.2E+10	0.05411	0.5324	169.6

Table E-1 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS-1 Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Medium	High	Total	0.8,0.8	0.8,1.5	0.8,2.5	1.0,0.8	1.0,1.0	1.0,1.5
251004	9.6	Jun-98	284	3	0	0	3	64.49	230900	3.7E+10	0.05952	0.5874	189.2
261001	2.2	Jul-88	203	0	0	0	0	712	2576000	4.1E+11	1.315	12.93	4136
261001	2.2	Sep-89	217	16	0	0	16	766.8	2766000	4.4E+11	1.418	13.95	4454
261001	2.2	Jul-90	227	24	0	0	24	793.8	2875000	4.6E+11	1.464	14.41	4613
261001	2.2	Jul-91	239	0	0	0		834.4	3024000	4.8E+11	1.538	15.14	4851
261001	2.2	Sep-91	241	51	0	0	51	846.3	3060000	4.9E+11	1.562	15.38	4919
261001	2.2	Sep-92	253	0	0	0		883.2	3200000	5.1E+11	1.628	16.03	5133
261001	2.2	Jun-93	262	23	0	0	23	908.4	3303000	5.3E+11	1.671	16.47	5283
261001	2.2	Jun-93	263	0	0	0		916	3324000	5.3E+11	1.688	16.62	5327
261001	2.2	May-95	285	9	0	0	9	984.9	3584000	5.8E+11	1.811	17.84	5727
261001	2.2	Jul-96	299	5	0	0	5	1038	3772000	6.1E+11	1.91	18.82	6039
261004	4.2	Sep-89	51	321	0	0	321	199.5	1097000	2.9E+11	0.1822	2.071	968.8
261004	4.2	Jul-90	61	451	0	0	451	239.4	1331000	3.6E+11	0.2174	2.483	1172
271018	4.4	Apr-89	124	0	0	0	0	745.8	4548000	1.4E+12	0.6463	7.64	3894
271018	4.4	Jun-89	126					759.8	4608000	1.4E+12	0.6581	7.764	3941
271018	4.4	Oct-90	142					875.2	5256000	1.6E+12	0.7558	8.886	4480
271018	4.4	Jun-93	174	41	1	0	41	1202	7343000	2.2E+12	1.061	12.58	6445
271018	4.4	Jul-93	176	7	51	0	57	1220	7394000	2.2E+12	1.079	12.75	6493
271018	4.4	Mar-94	183	58	39	0	98	1321	8128000	2.4E+12	1.176	13.98	7201
271018	4.4	Aug-94	188	131	0	0	131	1368	8338000	2.5E+12	1.215	14.39	7366
271087	15.7	Oct-91	154	0	0	0	0	329	2116000	6.5E+11	0.2852	3.454	1835
271087	15.7	May-93	173	8	0	0	8	386.7	2514000	7.7E+11	0.3358	4.084	2185
271087	15.7	Oct-94	190	24	0	0	24	430.7	2798000	8.6E+11	0.3734	4.541	2428
271087	15.7	Jun-96	210	25	0	0	25	457.5	2965000	9.1E+11	0.3953	4.803	2565
291008	11.4	Feb-92	70	0	0	0	0	2.158	15060	5.3E+09	0.00126	0.01577	9.042
291008	11.4	Mar-93	83	58	3	0	61	2.217	15260	5.3E+09	0.00129	0.01599	9.111
291008	11.4							2.217	15260	5.3E+09	0.00129	0.01599	9.111
291008	11.4	Apr-96	120	130	0	0	130	4.207	29850	1.1E+10	0.00251	0.03152	18.25
291008	11.4	Feb-00	152	26	0	0	26	4.735	32910	1.2E+10	0.00272	0.03392	19.43
307088	4.9	Sep-89	100	0	0	0	0	380.3	2074000	5.7E+11	0.3512	3.932	1775
307088	4.9	May-91	120	4	12	0	16	471.8	2594000	7.2E+11	0.4361	4.894	2219
308129	3.2	Oct-89	17					47.01	294700	9.6E+10	0.03581	0.4191	213.8
308129	3.2	Jul-91	38					199.9	1312000	4.3E+11	0.1591	1.918	1019
308129	3.2	Jul-92	50	0	0	0	0	266.5	1801000	6E+11	0.2099	2.562	1394
308129	3.2	Aug-93	63	0	0	0	0	314.9	2135000	7.2E+11	0.2464	3.005	1636
308129	3.2	Dec-93	67	0	0	0	0	328.4	2234000	7.5E+11	0.2564	3.13	1708
308129	3.2	Mar-94	70	0	0	0	0	370.2	2557000	8.7E+11	0.2915	3.581	1978
308129	3.2	Oct-94	77	0	0	0	0	450.2	3011000	1E+12	0.3602	4.376	2358
308129	3.2	Feb-95	81	0	0	0	0	488.9	3314000	1.1E+12	0.3899	4.76	2590
308129	3.2	May-95	84	0	0	0	0	496	3366000	1.1E+12	0.3938	4.81	2619
308129	3.2	Jun-96	97	0	0	0	0	569.4	3903000	1.3E+12	0.4507	5.523	3030
308129	3.2	Oct-96	101	0	0	0	0	577.9	3947000	1.3E+12	0.4564	5.585	3056
308129	3.2	Jan-97	104	0	0	0	0	597.5	4103000	1.4E+12	0.4704	5.767	3168
308129	3.2	Mar-97	106	0	0	0	0	608.9	4193000	1.4E+12	0.4777	5.862	3225

Table E-1 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS-1 Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Medium	High	Total	0.8,0.8	0.8,1.5	0.8,2.5	1.0,0.8	1.0,1.0	1.0,1.5
308129	3.2	Aug-97	111	0	0	0	0	622.2	4255000	1.4E+12	0.4887	5.976	3269
308129	3.2	Oct-97	113	0	0	0	0	626.1	4277000	1.4E+12	0.4913	6.004	3281
321020	7	Jul-91	86	34	0	0	34	118.3	563800	1.4E+11	0.08031	0.8596	349
321020	7	Aug-93	111	138	0	0	138	166.6	811600	2.1E+11	0.1133	1.221	506
321020	7	Sep-94	123	29	20	0	49	189.4	921900	2.3E+11	0.1283	1.383	571.9
321020	7	Apr-95	131	242	0	0	242	200.2	986400	2.5E+11	0.1345	1.454	605.5
321020	7	Jun-97	157	9	0	0		256.6	1253000	3.2E+11	0.1721	1.856	766.6
321020	7	Jun-98	169	0	0	0		288.9	1440000	3.7E+11	0.1938	2.105	886
341031	7.3	Apr-92	224	333	1	0	333	815.3	3031000	4.9E+11	0.8026	8.041	2688
341031	7.3	Feb-93	234	322	31	3	356	894.5	3312000	5.4E+11	0.8828	8.836	2946
341031	7.3	Oct-95	266	0	352	170	522	1203	4449000	7.2E+11	1.186	11.88	3961
341031	7.3	Nov-95	267	232	30	0	261	1207	4471000	7.2E+11	1.188	11.9	3974
341033	7.4	Apr-92	211	52	2	0	54	19.61	87080	1.9E+10	0.01219	0.1283	49.05
341033	7.4	Feb-93	221	32	11	0	44	20.71	91710	1.9E+10	0.01289	0.1355	51.7
341033	7.4	Nov-95	254	55	0	0	55	24.2	107100	2.3E+10	0.01504	0.1581	60.28
341033	7.4	Jul-97	274	260	0	0	260	26.18	117000	2.5E+10	0.01618	0.1706	65.56
341034	11.1	Oct-89	48	0	0	0	0	29.45	90900	1.2E+10	0.02175	0.2057	58.6
341034	11.1	Sep-90	59	0	0	0	0	37.29	114700	1.5E+10	0.02737	0.2591	73.93
341034	11.1	Apr-92	78	0	0	0	0	44.9	140900	1.9E+10	0.03236	0.3075	88.74
341034	11.1	Feb-93	88	0	0	0	0	52.92	166000	2.2E+10	0.03781	0.36	104.2
341034	11.1	Nov-95	121	3	0	0	3	79.44	252700	3.4E+10	0.05571	0.533	156.2
341034	11.1	Jul-97	141	0	15	0	15	94.06	300600	4E+10	0.06543	0.6272	184.5
350101	7.2	May-97	19	0	0	0	0	262.8	833800	1.1E+11	0.2516	2.409	715.2
350102	4.8	May-97	19	0	0	0	0	283.1	1183000	2.3E+11	0.2222	2.301	842.8
350103	12.5	May-97	19	0	0	0	0	0.04618	150	3.6E+07	1.5E-05	0.00014	0.03902
350104	19.2	May-97	19	0	0	0	0	7.649	15170	8.9E+08	0.00625	0.05379	11.78
350105	9.9	May-97	19	0	0	0	0	15.48	31760	2E+09	0.01116	0.09666	21.63
350106	15.6	May-97	19	0	0	0	0	1.518	2846	1.8E+08	0.00106	0.00896	1.891
351005	8.9	Oct-89	73	0	0	0	0	20.95	82120	1.6E+10	0.01261	0.1272	44.12
351005	8.9	Mar-91	90	0	0	0	0	25.61	105200	2.2E+10	0.01512	0.1543	55.41
351005	8.9	Oct-92	109	0	0	0	0	33.72	137100	2.8E+10	0.01974	0.2012	71.88
351005	8.9	Feb-94	125	0	0	0	0	40.58	167100	3.5E+10	0.02362	0.2414	86.94
351005	8.9	Mar-95	138	0	0	0	0	50.03	208600	4.4E+10	0.02915	0.299	109
351005	8.9	Apr-97	163	0	0	0	0	63.26	264600	5.6E+10	0.03636	0.3735	136.1
351022	6.3	Oct-89	37	0	0	0	0	33.24	152900	3.5E+10	0.02265	0.2404	95.12
351022	6.3	Mar-91	54	0	0	0	0	51.31	237300	5.6E+10	0.03466	0.3673	145
351022	6.3	Oct-92	73	0	0	0	0	84.32	393300	9.4E+10	0.0574	0.6106	243.8
351022	6.3	Feb-94	89	0	0	0	0	107.7	505700	1.2E+11	0.07285	0.776	310.7
351022	6.3	Mar-95	102	0	0	0	0	131.7	615800	1.5E+11	0.08891	0.9462	377.3
351022	6.3	Apr-97	127	0	0	0	0	189.9	892400	2.1E+11	0.1287	1.371	549.7
351112	6.3	Dec-89	67					565.5	2174000	4E+11	0.4634	4.613	1581
351112	6.3	Jan-91	80					662.2	2591000	4.9E+11	0.5343	5.36	1866
351112	6.3	Mar-91	82	0	0	0	0	675.1	2659000	5E+11	0.543	5.457	1909
351112	6.3	Jan-93	104	0	0	0	0	846.1	3369000	6.4E+11	0.6714	6.79	2403
351112	6.3	Feb-94	117	0	0	0	0	946.5	3788000	7.2E+11	0.7466	7.568	2690

Table E-1 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS-1 Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Medium	High	Total	0.8,0.8	0.8,1.5	0.8,2.5	1.0,0.8	1.0,1.0	1.0,1.5
351112	6.3	Oct-94	125	0	0	0	0	1022	4064000	7.7E+11	0.8069	8.172	2895
351112	6.3	Mar-95	130	14	0	0	14	1051	4238000	8.2E+11	0.825	8.387	3001
351112	6.3	Apr-95	131	0	0	0	0	1060	4276000	8.2E+11	0.8314	8.455	3028
351112	6.3	Jun-95	133	0	0	0	0	1080	4348000	8.4E+11	0.8472	8.615	3082
351112	6.3	Nov-96	150	0	0	0	0	1219	4917000	9.4E+11	0.9508	9.692	3479
351112	6.3	Apr-97	155	0	0	0	0	1244	5062000	9.8E+11	0.9668	9.875	3564
351112	6.3	Sep-97	160	0	0	0	0	1296	5236000	1E+12	1.009	10.29	3698
371024	4.8	Nov-89	109					37.16	162500	3.2E+10	0.03087	0.3274	127.2
371024	4.8	Mar-91	125					42.92	191200	3.9E+10	0.03518	0.3751	147.7
371024	4.8	Apr-92	138	3	0	0	3	48.53	217400	4.5E+10	0.03958	0.4227	167.2
371802	4.5	Mar-91	66					996	3164000	4E+11	1.604	15.48	4690
371802	4.5	Oct-92	85	28	0	0	28	1317	4154000	5.2E+11	2.129	20.54	6200
371802	4.5	Apr-94	103	0	0	0		1547	4961000	6.4E+11	2.481	24.02	7323
371802	4.5	Jul-95	118	41	0	0	41	1804	5732000	7.3E+11	2.909	28.09	8513
371802	4.5	Apr-96	127	0	0	0		1913	6124000	7.8E+11	3.071	29.71	9047
371992	2.4	Mar-91	14					294.3	972100	1.3E+11	0.4589	4.445	1351
371992	2.4	Oct-92	33	22	0	0	22	905.8	2817000	3.5E+11	1.507	14.4	4220
371992	2.4	Apr-94	51	0	0	0	0	1384	4414000	5.7E+11	2.279	21.85	6476
371992	2.4	Feb-96	73	0	0	0	0	2146	6894000	9E+11	3.534	33.96	10120
404087	10.1	Jan-90	43	0	0	0	0	3.621	7854	5.2E+08	0.00343	0.03018	7.067
404087	10.1	Oct-91	64	0	0	0	0	5.471	12200	8.3E+08	0.00505	0.04486	10.72
404087	10.1	Nov-92	77	31	0	0	31	6.425	14460	1E+09	0.00589	0.05245	12.62
404087	10.1	Feb-93	80	35	0	0	35	6.425	14460	1E+09	0.00589	0.05245	12.62
404087	10.1	Nov-94	101	143	0	0	143	8.303	19010	1.3E+09	0.00748	0.06697	16.32
404087	10.1	Feb-95	104	112	0	0	112	8.303	19010	1.3E+09	0.00748	0.06697	16.32
404087	10.1	Aug-95	110	0	159	0	159	9.779	22500	1.6E+09	0.00879	0.07882	19.29
404087	10.1	Jun-97	132	10	0	0	10	11.93	27760	2E+09	0.01062	0.09558	23.57
404163	11.5	Jan-90	34					1.815	4375	3.6E+08	0.00102	0.00917	2.273
404163	11.5	Mar-91	48					2.368	5802	4.9E+08	0.00132	0.01192	2.991
404163	11.5	Oct-91	55	0	0	0	0	2.742	6805	5.8E+08	0.0015	0.01363	3.452
404163	11.5	Nov-92	68	0	0	0	0	3.469	8657	7.4E+08	0.00191	0.01738	4.429
404163	11.5	Mar-93	72	7	0	0	7	3.478	8728	7.6E+08	0.00191	0.0174	4.443
404163	11.5	Nov-94	92	0	0	0	0	4.412	11220	9.8E+08	0.0024	0.02194	5.663
404163	11.5	Apr-96	109	0	0	0	0	4.764	12210	1.1E+09	0.00257	0.02351	6.098
404163	11.5	Aug-97	125	45	8	0	53	6.02	15520	1.4E+09	0.00326	0.0299	7.799
404163	11.5	Jan-99	141	6	9	0	15	6.55	17020	1.6E+09	0.00352	0.03239	8.492
404165	8.1	Jan-90	68					97.84	358100	6.4E+10	0.06452	0.6303	201.7
404165	8.1	Mar-91	82					114.5	425900	7.7E+10	0.07432	0.7301	236.7
404165	8.1	Oct-91	89	4	0	0	4	129	477300	8.5E+10	0.08345	0.821	266.5
404165	8.1	Nov-92	102	5	0	0	5	143.8	542900	9.9E+10	0.09159	0.9063	298.7
404165	8.1	Mar-93	106	19	0	0	19	144.9	551100	1E+11	0.09192	0.9104	301.1
404165	8.1	Oct-94	125	9	0	0	9	180.8	680600	1.2E+11	0.1151	1.14	375.2
404165	8.1	Nov-94	126	16	0	0	16	181.2	683200	1.2E+11	0.1152	1.141	376
404165	8.1	Apr-95	131	24	0	0	24	183.6	698100	1.3E+11	0.1162	1.152	381.5

Table E-1 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS-1 Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Medium	High	Total	0.8,0.8	0.8,1.5	0.8,2.5	1.0,0.8	1.0,1.0	1.0,1.5
404165	8.1	Jun-95	133	25	0	0	25	187.4	713500	1.3E+11	0.1184	1.175	389.7
404165	8.1	Apr-96	143	25	0	0	25	201.1	771900	1.4E+11	0.1263	1.257	419.2
404165	8.1	Nov-96	150	60	0	0	60	215.6	824300	1.5E+11	0.1354	1.347	449.1
404165	8.1	May-97	156	26	0	0	26	219.1	843300	1.6E+11	0.137	1.365	456.8
404165	8.1	Sep-97	160	24	0	0	24	229	878200	1.6E+11	0.143	1.425	477
421599	12.3	Aug-89	25					8.385	28040	4.5E+09	0.00518	0.05013	16.28
421599	12.3	Sep-90	38					11.57	42060	7.3E+09	0.00699	0.0695	24.13
421599	12.3	Mar-93	68	0	0	0	0	20.72	80750	1.5E+10	0.01252	0.1267	45.92
421599	12.3	Sep-94	86	0	0	0	0	27.04	103400	1.9E+10	0.01649	0.1659	59.2
421599	12.3	Jun-95	95	8	0	0	8	30.15	118600	2.2E+10	0.01817	0.1844	67.14
421599	12.3	Jul-96	108	4	0	0	4	33.07	125000	2.3E+10	0.02018	0.202	71.12
421599	12.3	Mar-98	128	2	0	0	2	42.37	161000	2.9E+10	0.02626	0.2627	92.55
451011	3.2	Mar-92	69	0	0	0	0	1939	6609000	9.9E+11	2.338	22.61	6906
451011	3.2	Oct-92	76	0	0	0	0	2203	7422000	1.1E+12	2.678	25.87	7860
451011	3.2	Jun-93	84	0	0	0	0	2321	7997000	1.2E+12	2.771	26.88	8274
451011	3.2	Jan-96	115	16	0	0	16	3226	1.1E+07	1.7E+12	3.853	37.46	11570
451011	3.2	Jun-97	132	0	0	0	0	3637	1.3E+07	1.9E+12	4.313	42.01	13050
451011	3.2	Feb-99	150	0	0	0	0	4135	1.4E+07	2.2E+12	4.886	47.67	14850
473104	1.3	Aug-89	39					125.3	460200	7.6E+10	0.4149	4.12	1366
473104	1.3	Nov-89	42					132.2	489200	8.2E+10	0.4336	4.316	1439
473104	1.3	May-91	60					178.3	712100	1.3E+11	0.5534	5.624	1982
473104	1.3	Aug-91	63					186.9	738000	1.3E+11	0.5793	5.875	2058
473104	1.3	Oct-92	77					226.3	902600	1.6E+11	0.6874	7.004	2479
473104	1.3	Aug-93	87					259.5	1049000	1.9E+11	0.78	7.987	2859
473104	1.3	Nov-95	114					357.2	1489000	2.8E+11	1.053	10.9	4005
473104	1.3	Oct-96	125					406.7	1699000	3.2E+11	1.198	12.42	4582
480001	2.4	Apr-89	1					40.86	114000	1.1E+10	0.07134	0.6641	181.7
480001	2.4	Oct-90	19					1167	2867000	2.7E+11	2.541	22.43	5439
480001	2.4	May-91	26	0	0	0	0	1382	3711000	4.1E+11	2.836	25.42	6476
480001	2.4	Feb-93	47	0	0	0	0	2716	7409000	8.5E+11	5.577	50.18	12900
480001	2.4	Apr-93	49	0	0	0	0	2791	7703000	9E+11	5.677	51.21	13260
480001	2.4	Feb-95	71	0	0	0	0	4209	1.2E+07	1.5E+12	8.272	75.49	20120
480001	2.4	Mar-95	72	0	0	0	0	4243	1.2E+07	1.5E+12	8.309	75.89	20280
480001	2.4	May-97	98	34	0	0	34	6329	1.9E+07	2.3E+12	12.22	112.2	30370
480001	2.4	Mar-98	108	34	0	0	34	7215	2.1E+07	2.7E+12	13.86	127.5	34720
481060	7.5	Jun-90	52	0	0	0	0	1590	5283000	6.9E+11	1.254	12.29	3847
481060	7.5	Feb-91	60	0	0	0	0	1827	6093000	8E+11	1.437	14.11	4427
481060	7.5	Apr-91	62	0	0	0	0	1867	6259000	8.3E+11	1.463	14.38	4525
481060	7.5	Mar-92	73	12	0	0	12	2243	7575000	1E+12	1.748	17.23	5456
481060	7.5	Feb-93	84	19	0	0	19	2657	9016000	1.2E+12	2.065	20.38	6479
481060	7.5	Mar-93	85	23	0	0	23	2679	9112000	1.2E+12	2.078	20.52	6533
481060	7.5	Oct-94	104	14	0	0	14	3479	1.2E+07	1.6E+12	2.691	26.64	8518
481060	7.5	Feb-95	108	28	0	0	28	3513	1.2E+07	1.6E+12	2.707	26.83	8597
481060	7.5	Mar-95	109	0	0	0		3528	1.2E+07	1.6E+12	2.715	26.91	8631

Table E-1 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS-1 Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Medium	High	Total	0.8,0.8	0.8,1.5	0.8,2.5	1.0,0.8	1.0,1.0	1.0,1.5
481060	7.5	Mar-95	112	14	0	0	14	3690	1.3E+07	1.7E+12	2.837	28.14	9035
481060	7.5	Jun-95	134	8	0	0	8	4599	1.6E+07	2.2E+12	3.508	34.91	11290
481060	7.5	Apr-97	137	31	0	0	31	4833	1.7E+07	2.3E+12	3.694	36.75	11880
481060	7.5	Jul-97	139	31	2	0	33	5005	1.7E+07	2.4E+12	3.835	38.13	12310
481060	7.5	Sep-97	154	32	0	0	32	5679	2E+07	2.7E+12	4.327	43.11	13980
481077	5.1	Apr-89	88					374.1	1633000	3.3E+11	0.2127	2.25	873.5
481077	5.1	Nov-91	119	0	0	0	0	514.7	2235000	4.5E+11	0.2919	3.085	1194
481077	5.1	Oct-92	130	28	0	0	28	566.8	2471000	5E+11	0.3208	3.395	1318
481077	5.1	May-93	137	124	0	0	124	594.6	2620000	5.3E+11	0.3349	3.555	1390
481077	5.1	Oct-94	154	143	0	0	143	679.7	2972000	6E+11	0.3834	4.061	1579
481077	5.1	Mar-95	159	47	0	0	47	700.2	3089000	6.3E+11	0.3935	4.179	1635
481077	5.1	Apr-95	160	181	0	0	181	705.6	3114000	6.3E+11	0.3965	4.212	1648
481077	5.1	Jun-95	162	181	0	0	181	717.4	3157000	6.4E+11	0.4035	4.284	1673
481077	5.1	Aug-95	164	181	0	0	181	728.6	3189000	6.4E+11	0.4105	4.35	1693
481077	5.1	Jun-96	174	181	0	0	181	775.1	3416000	6.9E+11	0.4353	4.622	1807
481077	5.1	May-97	185	228	10	0	238	831.2	3684000	7.5E+11	0.466	4.956	1946
481077	5.1	Jul-97	187	300	0	0	300	843.3	3724000	7.6E+11	0.4733	5.029	1969
481077	5.1	Sep-97	189	276	0	0	276	855.3	3765000	7.6E+11	0.4804	5.101	1994
481077	5.1	Mar-98	195	281	0	0	281	879.7	3910000	8E+11	0.4922	5.239	2061
481109	6.5	Jan-90	68					636.1	2124000	3E+11	0.7427	7.24	2261
481109	6.5	Sep-90	76					737.3	2454000	3.4E+11	0.8627	8.411	2624
481109	6.5	May-91	84	123	0	0	123	796	2703000	3.9E+11	0.9212	9.026	2853
481109	6.5	Feb-93	105	148	0	0	148	1031	3517000	5.1E+11	1.191	11.69	3708
481109	6.5	Jul-93	110	336	0	0	336	1104	3762000	5.4E+11	1.276	12.53	3975
481109	6.5	Feb-95	129	502	3	0	505	1314	4521000	6.6E+11	1.511	14.88	4750
481109	6.5	May-95	132	571	0	0	571	1349	4656000	6.8E+11	1.548	15.26	4883
481109	6.5	Aug-96	147	425	0	0	425	1579	5437000	7.9E+11	1.814	17.89	5722
481130	2.7	Apr-89	200	0	0	0	0	4147	1E+07	9.1E+11	8.725	77.27	18700
481130	2.7	Oct-90	218	0	0	0	0	4703	1.1E+07	1E+12	9.897	87.69	21230
481130	2.7	Mar-91	223	15	0	0	15	4739	1.2E+07	1E+12	9.937	88.11	21380
481130	2.7	Mar-92	235	35	0	0	35	5030	1.2E+07	1.1E+12	10.52	93.35	22690
481169	1.1	Feb-90	211					37120	1.6E+08	3.3E+13	91.28	973.3	380700
481169	1.1	Mar-90	212					37290	1.7E+08	3.3E+13	91.65	977.7	382700
481169	1.1	Sep-90	218					38600	1.7E+08	3.4E+13	95.11	1013	394600
481169	1.1	Jan-91	222	0	0	0	0	39270	1.7E+08	3.5E+13	96.53	1030	402700
481169	1.1	Mar-91	224	0	0	0	0	39610	1.8E+08	3.5E+13	97.26	1038	406900
481169	1.1	Jun-91	227	0	0	0	0	40250	1.8E+08	3.6E+13	98.93	1055	413000
481169	1.1	Jan-92	234	0	0	0	0	41630	1.8E+08	3.7E+13	102.3	1091	427000
481169	1.1	Feb-93	247	0	0	0	0	44210	2E+08	3.9E+13	108.6	1159	454000
481169	1.1	Aug-93	253	0	0	0	0	45510	2E+08	4E+13	111.9	1193	466400
481169	1.1	Mar-95	272	7	0	0	7	49250	2.2E+08	4.4E+13	120.8	1290	506800
481169	1.1	Jul-95	276	0	0	0	0	50160	2.2E+08	4.4E+13	123.1	1315	515300
481169	1.1	Jul-97	300	0	0	0	0	55120	2.4E+08	4.9E+13	135.2	1444	566700
481174	4.7	Oct-90	186					611.6	2207000	3.3E+11	0.3966	3.995	1348

Table E-1 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS-1 Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Medium	High	Total	0.8,0.8	0.8,1.5	0.8,2.5	1.0,0.8	1.0,1.0	1.0,1.5
481174	4.7	Feb-91	190					620.7	2250000	3.4E+11	0.4018	4.053	1372
481174	4.7	Apr-91	192	201	0	0	201	627.1	2277000	3.4E+11	0.4057	4.094	1387
481174	4.7	Mar-92	203	204	0	0	204	665.7	2418000	3.7E+11	0.43	4.34	1472
481174	4.7	Feb-93	214	138	0	0	138	701.9	2552000	3.9E+11	0.4525	4.569	1550
481174	4.7	Mar-93	215	185	0	0	185	704.1	2562000	3.9E+11	0.4538	4.583	1556
481174	4.7	Feb-95	238	220	10	0	229	783.3	2852000	4.3E+11	0.5035	5.086	1728
481174	4.7	Mar-95	239	179	0	0	179	785.8	2863000	4.3E+11	0.5049	5.102	1734
481174	4.7	Jan-96	249	160	0	0	160	822.2	2994000	4.5E+11	0.5278	5.333	1812
481174	4.7	Apr-97	264	0	0	0		873.1	3187000	4.8E+11	0.5595	5.658	1926
481174	4.7	Mar-98	275	49	0	0	49	907.6	3317000	5E+11	0.5808	5.876	2002
481178	8.5	Apr-89	10	78	0	0	78	4.13	6721	3.3E+08	0.00441	0.03486	6.305
481178	8.5	Feb-91	32	61	0	0	61	11.26	21420	1.3E+09	0.00949	0.07836	15.91
481178	8.5	May-91	33	48	0	0	48	11.32	21590	1.3E+09	0.00951	0.0786	15.98
481178	8.5	Feb-93	56	44	0	0	44	17.73	36040	2.3E+09	0.01361	0.1149	24.62
481178	8.5	Jul-93	61	94	0	0	94	19.79	40700	2.6E+09	0.01491	0.1264	27.39
481178	8.5	Feb-95	80	92	0	0	92	25.35	53700	3.6E+09	0.01834	0.157	34.91
481178	8.5	Mar-95	81	57	0	0	57	25.41	53880	3.6E+09	0.01836	0.1573	34.99
481183	5.7	Sep-90	188	0	0	0	0	1438	4487000	5.8E+11	1.754	16.82	5033
481183	5.7	Mar-91	194	0	0	0	0	1463	4604000	6.1E+11	1.777	17.07	5128
481183	5.7	Oct-91	201	4	0	0	4	1676	5214000	6.8E+11	2.044	19.59	5849
481183	5.7	Nov-91	202	11	0	0	11	1680	5236000	6.8E+11	2.047	19.62	5864
481183	5.7	Jan-93	216	19	0	0	19	1914	6012000	7.9E+11	2.323	22.31	6698
481183	5.7	Jul-93	222	3	0	0	3	2073	6512000	8.5E+11	2.515	24.17	7261
481183	5.7	Apr-94	231	3	0	0	3	2223	7006000	9.2E+11	2.69	25.86	7782
483749	1.8	Oct-90	116	0	0	0	0	15160	4.6E+07	5.5E+12	29.68	280.5	80490
483749	1.8	Apr-91	122	0	0	0	0	15560	4.8E+07	5.8E+12	30.22	286.3	82620
483749	1.8	Aug-91	126	0	0	0	0	16190	4.9E+07	6E+12	31.47	298	85880
483749	1.8	Mar-92	133	0	0	0	0	16750	5.2E+07	6.4E+12	32.32	306.7	88860
483749	1.8	Feb-93	144	0	0	0	0	17960	5.6E+07	6.9E+12	34.51	327.8	95250
483749	1.8	Mar-93	145	0	0	0	0	18040	5.6E+07	6.9E+12	34.63	329	95660
483749	1.8	Feb-95	168	0	0	0	0	20490	6.4E+07	8E+12	38.97	371.1	108500
483749	1.8	Mar-95	169	0	0	0	0	20560	6.4E+07	8.1E+12	39.06	372.1	108900
483749	1.8	Mar-97	193	2	0	0	2	23060	7.3E+07	9.2E+12	43.44	414.8	122100
489005	1.2	Oct-90	50	169	0	0	169	27920	9E+07	1.2E+13	117.7	1143	351700
489005	1.2	Mar-91	55	215	0	0	215	29950	9.9E+07	1.3E+13	125.3	1220	378900
489005	1.2	Aug-91	60	223	0	0	223	32490	1.1E+08	1.5E+13	135.5	1321	411500
489005	1.2	Feb-93	78	106	0	0	106	41640	1.4E+08	1.9E+13	172.3	1686	529700
489005	1.2	Apr-93	80	240	0	0	240	42260	1.4E+08	2E+13	174.3	1708	538500
489005	1.2	Feb-95	102	169	0	0	169	52680	1.8E+08	2.5E+13	215.3	2118	673000
489005	1.2	Feb-96	114	274	0	0	274	58520	2E+08	2.8E+13	238.6	2349	748000
489005	1.2	Jul-96	119	253	0	0	253	60630	2.1E+08	2.9E+13	246.3	2429	776500
489005	1.2	Jul-97	131	325	0	0	325	66470	2.3E+08	3.2E+13	269.3	2659	852700
489005	1.2	Jul-98	143	278	0	0	278	72320	2.5E+08	3.6E+13	292.4	2890	929300

Table E-1 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS-1 Model.

Section	Total Asphalt Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Medium	High	Total	0.8,0.8	0.8,1.5	0.8,2.5	1.0,0.8	1.0,1.0	1.0,1.5
501002	8.5	Aug-89	58					39.34	226400	6.1E+10	0.02785	0.3285	163.8
501002	8.5	Aug-90	70					48.54	279700	7.6E+10	0.03427	0.4044	201.7
501002	8.5	May-94	115	2	0	0	2	85.43	501200	1.4E+11	0.06118	0.7267	366.8
501002	8.5	Aug-94	118	0	0	0	0	87.57	509200	1.4E+11	0.06249	0.7403	371.6
501002	8.5	Apr-95	126	8	0	0	8	91.13	531200	1.4E+11	0.0646	0.7658	384.6
501002	8.5	Oct-96	144	16	0	0	16	115.6	677000	1.8E+11	0.08382	0.9962	501.8
501002	8.5	May-97	151	66	125	0	191	116.6	681800	1.8E+11	0.08427	1.001	503.8
501002	8.5	Oct-97	156	10	5	0	14	124.1	721100	1.9E+11	0.08937	1.059	530.6
501002	8.5	Jun-98	164	10	26	0	36	126.3	730900	2E+11	0.09049	1.071	535.2
501004	8	Apr-93	102	34	11	0	44	17.02	123400	4.3E+10	0.01351	0.1711	99.5
501004	8	Oct-95	132	8	4	0	12	22.89	163400	5.6E+10	0.01704	0.2147	123.7
501004	8	Nov-97	157	7	3	0	9	33.84	242900	8.4E+10	0.02523	0.3186	184.1
511002	5.7	Apr-89	115	9	42	59	110	585.7	2489000	4.8E+11	0.5969	6.258	2355
511023	10.1	Oct-89	107	0	0	0	0	115	341600	3.7E+10	0.07796	0.7445	215.7
511023	10.1	Mar-91	124	0	0	0	0	130	386900	4.2E+10	0.08804	0.8414	244.2
511023	10.1	May-92	138	0	0	0	0	144.6	432900	4.7E+10	0.09735	0.9321	271.7
511023	10.1	Oct-92	143	21	0	0	21	159.8	477900	5.2E+10	0.108	1.034	301.4
511023	10.1	Dec-93	157	0	0	0		175.6	525900	5.7E+10	0.1187	1.136	331.3
511023	10.1	Sep-95	178	105	0	0	105	208.5	626500	6.8E+10	0.1405	1.348	394.2
511023	10.1	Feb-96	183	167	0	0	167	208.9	628400	6.9E+10	0.1407	1.349	394.9
511023	10.1	Mar-97	196	4	0	0	4	223.3	674000	7.4E+10	0.1498	1.439	422.2
512021	7.5	Oct-89	54					180.6	719800	1.3E+11	0.1481	1.517	537.9
512021	7.5	Mar-91	71					230.3	934000	1.7E+11	0.1869	1.921	687.3
512021	7.5	Oct-92	90	21	0	0	21	316.4	1276000	2.3E+11	0.2582	2.654	947.5
531008	3.4	Jul-91	153	6	0	0	6	349.2	1453000	3E+11	0.3589	3.539	1193
531008	3.4	Jun-93	176	66	0	0	67	399.4	1679000	3.5E+11	0.4054	4.012	1365
531008	3.4	Jun-94	188	8	5	8	21	432.2	1819000	3.8E+11	0.438	4.338	1478
561007	2.8	Jul-90	121					162.7	620700	1.2E+11	0.2106	2.031	643.5
561007	2.8	May-91	131	0	0	0	0	173.7	671400	1.3E+11	0.2226	2.154	689.6
561007	2.8	Aug-91	134	0	0	0	0	183.4	694400	1.4E+11	0.2395	2.304	726.2
561007	2.8	Aug-93	158	13	0	0	13	214.2	808100	1.6E+11	0.2802	2.694	846.6
561007	2.8	Oct-93	160	26	0	0	26	216.2	817400	1.6E+11	0.2822	2.716	854.7
561007	2.8	Dec-93	162	4	0	0	4	218	829200	1.6E+11	0.2835	2.731	863.3
561007	2.8	Mar-94	165	6	0	0	6	220.7	847900	1.7E+11	0.2855	2.756	877
561007	2.8	Apr-94	166	0	0	0		221.6	852700	1.7E+11	0.2862	2.764	880.5
561007	2.8	Aug-94	170	6	0	0	6	229.2	875000	1.7E+11	0.2975	2.87	909.6
561007	2.8	Feb-95	176	7	0	0	7	235.2	908800	1.8E+11	0.303	2.931	937.1
561007	2.8	May-95	179	0	0	0		237.7	919800	1.8E+11	0.3055	2.957	946.6
561007	2.8	Sep-95	183	0	0	0		245.8	942700	1.9E+11	0.3177	3.07	977.3
561007	2.8	Jun-96	192	5	0	0	5	254.3	983400	2E+11	0.3266	3.163	1013
561007	2.8	Oct-96	196	0	0	0		263.6	1008000	2E+11	0.3421	3.302	1048
561007	2.8	Nov-96	197	2	0	0	2	264.1	1010000	2E+11	0.3424	3.305	1050
561007	2.8	Mar-97	201	0	0	0		266.5	1026000	2E+11	0.3439	3.324	1059
561007	2.8	Aug-97	206	3	0	0	3	278.9	1058000	2.1E+11	0.3645	3.509	1106

561007	2.8	Sep-97	207	0	0	0		280.6	1063000	2.1E+11	0.3669	3.532	1113

Table E-2 Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS1 Model.

Section	Total AC Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Med	High	Total	1.0,2.5	1.2,0.8	1.2,1.5 (Ave Thermal)	1.2,1.5 (No Thermal)	1.2,1.5 (max Thermal)	1.2,2.5
11001	3.2	Sep-91	132	0	0	0	0	8.2E+08	0.00223	6.201	5.93698	6.321	748900
11001	3.2	Apr-92	139	16	0	0	16	9E+08	0.0023	6.512	6.25489	6.659	809800
11001	3.2	Jul-92	142	14	0	0	14	9.1E+08	0.00239	6.705	6.42577	6.852	822400
11001	3.2	Jan-93	148	30	0	0	30	9.5E+08	0.00249	7	6.71189	7.174	862500
11019	6.7	May-89	32					5.2E+07	8.7E-05	0.2887	0.28546	0.3495	37880
11019	6.7	Apr-90	43					7E+07	0.00012	0.3837	0.37945	0.4595	50560
11019	6.7	Jan-91	52					8.3E+07	0.00014	0.4631	0.45789	0.5527	59960
11019	6.7	Jun-91	57	4	0	0	4	9.2E+07	0.00015	0.5079	0.50214	0.601	66110
11019	6.7	Mar-92						1.1E+08	0.00017	0.5759	0.56951	0.6788	75900
11019	6.7	Mar-93	78	139	0	0	139	1.3E+08	0.0002	0.6826	0.6751	0.8047	91520
11019	6.7	Jul-95	106	0	0	0		2.1E+08	0.00036	1.191	1.1769	1.374	156500
11019	6.7	Jan-98	136	0	0	0		2.7E+08	0.00046	1.531	1.51278	1.758	203100
14126	13.1	Jun-89	15	0	0	0	0	2961000	0.0001	0.1514	0.04933	0.02122	5212
14126	13.1	Mar-91	36	0	0	0	0	5756000	0.00017	0.2615	0.1209	0.2954	9504
14126	13.1	Mar-93	60	0	0	0	0	8147000	0.00021	0.3326	0.1721	0.4433	12670
14126	13.1	Apr-94	73	0	0	0	0	9584000	0.00024	0.3741	0.2057	0.7572	14560
14126	13.1	Dec-95	93	0	0	0	0	1.2E+07	0.00028	0.4471	0.2713	0.7591	17820
14126	13.1	Dec-97	117	0	0	0	0	1.5E+07	0.00032	0.5144	0.3278	0.9258	21000
21001	3	May-90	83	0	0	0	0	1.5E+08	0.00011	0.553	0.36955	534.1	129600
21001	3	Aug-91	98	0	0	0	0	1.8E+08	0.00015	0.7012	0.45136	552.6	160100
21001	3	Aug-93	122	27	0	0	27	2.3E+08	0.00018	0.874	0.55591	728.2	205000
21001	3	Jun-95	144	0	0	0	0	3E+08	0.00021	1.087	0.64433	728.3	264900
21001	3	Aug-97	170	0	0	0	0	3.5E+08	0.00026	1.305	0.7688	728.5	313600
21001	3	Aug-98	182	0	0	0	0	3.9E+08	0.00028	1.412	0.82482	728.6	344300
21002	3.3	May-90	68	0	0	0	0	2.8E+07	2.5E-05	0.09913	0.08125	52.52	20190
21002	3.3	Aug-91	83	6	0	0	6	3.4E+07	3.4E-05	0.1315	0.10731	76.5	25550
21002	3.3	Aug-93	107	0	0	0	0	4.4E+07	4.5E-05	0.1702	0.14205	79.86	32800
21002	3.3	Jun-95	129	0	0	0	0	5.9E+07	5.8E-05	0.2238	0.17453	104.3	45000
21002	3.3	Aug-97	155	0	0	0	0	6.8E+07	6.6E-05	0.2572	0.20306	104.4	51840
21002	3.3	May-98	164	0	0	0	0	7.7E+07	6.9E-05	0.2797	0.21084	104.4	58980
40113	4.5	Feb-95	19	0	0	0	0	3.8E+08	0.00034	1.234	1.00236	7.324	241800
40113	4.5	Mar-95	20	11	0	0	11	4.1E+08	0.00035	1.293	1.0427	7.626	257000
40113	4.5	Aug-95	25	0	0	0	0	4.8E+08	0.00047	1.637	1.34506	8.32	301800
40113	4.5	Nov-95	28	0	0	0	0	5.3E+08	0.00051	1.819	1.47914	8.543	336400
40113	4.5	Feb-96	31	0	0	0	0	6.4E+08	0.00054	2.027	1.62744	11.38	400900
40113	4.5	Apr-96	33	0	0	0	0	6.9E+08	0.00057	2.149	1.71312	11.75	429300
40113	4.5	Jul-96	36	0	0	0	0	7.2E+08	0.00066	2.403	1.95823	12.02	452700

Table E-2 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS-1 Model.

Section	Total AC Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Med	High	Total	1.0,2.5	1.2,0.8	1.2,1.5 (Ave Thermal)	1.2,1.5 (No Thermal)	1.2,1.5 (max Thermal)	1.2,2.5
40113	4.5	Aug-96	37	0	0	0	0	7.3E+08	0.0007	2.499	2.05274	12.12	461100
40113	4.5	Jan-98	54	53	17	0	70	1.2E+09	0.001	3.794	3.06125	19.25	755600
40113	4.5	Apr-98	57	17	65	0	82	1.3E+09	0.00104	4.035	3.23375	20.79	827100
40113	4.5	Jun-98	59	24	59	0	83	1.4E+09	0.00108	4.181	3.34555	20.99	850700
40113	4.5	Oct-98	63	0	173	0	173	1.4E+09	0.0012	4.57	3.69478	21.4	900200
40114	6.8	Feb-95	19	0	0	0	0	2.3E+08	0.00045	1.358	1.38517	4.714	165600
40114	6.8	Mar-95	20	31	0	0	31	2.5E+08	0.00046	1.401	1.43008	4.955	173400
40114	6.8	Aug-95	25	0	0	0	0	3.3E+08	0.00068	2.046	2.08161	5.958	242800
40114	6.8	Nov-95	28	0	0	0	0	3.9E+08	0.00077	2.358	2.39699	6.286	284200
40114	6.8	Feb-96	31	7	0	0	7	4.1E+08	0.00078	2.403	2.44793	7.762	294800
40114	6.8	Apr-96	33	9	0	0	9	4.4E+08	0.00082	2.544	2.59238	8.102	315800
40114	6.8	Jul-96	36	44	0	0	44	5E+08	0.00101	3.058	3.10918	8.676	366600
40114	6.8	Aug-96	37	0	0	0		5.2E+08	0.00107	3.252	3.30424	8.87	385500
40114	6.8	Jan-98	54	33	40	26	98	7.8E+08	0.00154	4.736	4.81275	12.81	571800
40114	6.8	Apr-98	57	0	41	0	41	8.1E+08	0.00156	4.834	4.91665	13.53	588600
40114	6.8	Jun-98	59	0	42	0	42	8.6E+08	0.00165	5.127	5.21493	13.92	625200
40114	6.8	Oct-98	63	38	23	0	61	9.6E+08	0.00189	5.849	5.93885	14.66	706700
40115	15.1	Feb-95	19	0	0	0	0	3.8E+07	0.00075	1.206	1.196	2.48	48750
40115	15.1	Mar-95	20	33	0	0	33	3.8E+07	0.00075	1.209	1.198	2.492	48930
40115	15.1	Jan-98	54	0	0	0	0	1.2E+08	0.00165	2.908	2.878	7.305	135500
40116	16.2	Feb-95	19	0	0	0	0	1.2E+07	0.00014	0.2618	0.2595	0.6168	13130
40116	16.2	Mar-95	20	18	0	0	18	1.3E+07	0.00014	0.2623	0.2599	0.6217	13180
40116	16.2	Jan-98	54	0	0	0	0	3.6E+07	0.00028	0.5791	0.5732	1.604	33340
40117	11.8	Feb-95	19	0	0	0	0	1.1E+07	0.00011	0.2046	0.1981	0.7893	10130
40117	11.8	Mar-95	20	14	0	0	14	1.1E+07	0.00011	0.2048	0.1982	0.8039	10150
40117	11.8	Jan-98	54	0	0	0	0	3.2E+07	0.00022	0.4514	0.4343	2.051	25760
40118	11.7	Feb-95	19	0	0	0	0	4233000	2.9E-05	0.05474	0.05394	0.403	2919
40118	11.7	Mar-95	20	15	0	0	15	4236000	2.9E-05	0.05475	0.05395	0.4096	2920
40118	11.7	Jan-98	54	0	0	0	0	1.3E+07	5.7E-05	0.1219	0.1197	1.126	7714
41007	6.5	Sep-91	162	0	0	0	0	1.8E+08	0.00016	0.5854	0.57635	0.6356	93330
41007	6.5	Feb-93	163	57	0	0	57	1.8E+08	0.00016	0.5901	0.58104	0.6403	94400
41007	6.5	Sep-94	198	167	0	0	167	2.4E+08	0.00022	0.795	0.783	0.8626	128700
41024	10.8	Nov-89	149					4.8E+08	0.00178	4.169	4.166	12.56	316700
41024	10.8	Aug-90	158					5.3E+08	0.00196	4.616	4.61	14.38	351900
41024	10.8	Oct-92	184	0	0	0	0	6.7E+08	0.00244	5.797	5.796	18.57	446000
41024	10.8	Mar-95	213	9	0	0	9	8.2E+08	0.00287	6.89	6.896	25.73	536600
41024	10.8	Jul-95	217	23	0	0	23	8.7E+08	0.00305	7.33	7.334	26.18	571000
41024	10.8	Aug-95	218	127	0	0	127	8.9E+08	0.00313	7.513	7.515	26.36	585700
41024	10.8	Nov-95	221	109	0	0	109	9.1E+08	0.00317	7.621	7.626	26.92	595700
41024	10.8	Feb-96	224	61	0	0	61	9.1E+08	0.00317	7.621	7.626	27.1	595700

Table E-2 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS-1 Model.

Section	Total AC Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Med	High	Total	1.0,2.5	1.2,0.8	1.2,1.5 (Ave Thermal)	1.2,1.5 (No Thermal)	1.2,1.5 (max Thermal)	1.2,2.5
41024	10.8	Apr-96	226	79	0	23	102	9.1E+08	0.00317	7.63	7.636	27.15	596600
41024	10.8	Jun-96	228	59	0	0	59	9.3E+08	0.00322	7.76	7.765	27.3	607200
41024	10.8	Aug-96	230	59	0	0	59	9.8E+08	0.00343	8.251	8.253	27.79	644000
41024	10.8	Apr-98	250	49	0	4	53	1.1E+09	0.00378	9.131	9.144	31.95	716300
41024	10.8	Jun-98	252	49	0	4	53	1.1E+09	0.00386	9.327	9.339	32.15	731400
41024	10.8	Oct-98	256	50	0	4	54	1.2E+09	0.00401	9.732	9.759	35.42	768400
81029	4.2	Oct-91	233	0	25	0	25	1.2E+08	8.4E-05	0.3977	0.44921	1292	99960
81029	4.2	Jul-94	266	44	0	0	44	1.4E+08	9.5E-05	0.4563	0.51241	1458	115900
81029	4.2	Sep-95	280	11	0	0	11	1.5E+08	9.9E-05	0.4783	0.53816	1511	121400
81053	4.6	Oct-89	60					8.1E+07	7.4E-05	0.322	0.66249	367.3	70250
81053	4.6	Jul-90	69					9.3E+07	7.8E-05	0.3484	0.78522	385.1	79040
81053	4.6	Apr-93	102	92	0	0	92	1.7E+08	0.00013	0.6138	1.35658	743.6	142600
81053	4.6	Nov-93	109	18	0	0	18	2E+08	0.00019	0.8077	1.54624	744.5	172800
81053	4.6	Dec-93	110	33	0	0	33	2E+08	0.00019	0.8113	1.55343	746.3	174100
81053	4.6	Oct-94	120	108	0	0	108	2.5E+08	0.00026	1.074	1.80151	768.7	223900
81053	4.6	Feb-95	124	228	0	0	228	2.8E+08	0.00026	1.138	1.83639	1141	246900
81053	4.6	May-95	127	229	0	0	229	2.8E+08	0.00027	1.144	1.91182	1144	248800
81053	4.6	May-96	139	0	0	0		3E+08	0.00027	1.173	2.20611	1238	258000
81053	4.6	Oct-96	144	0	0	0		3E+08	0.00027	1.179	2.38705	1238	259000
81053	4.6	Nov-96	145	33	0	0		3E+08	0.00027	1.18	2.40231	1238	259500
81053	4.6	Mar-97	149	45	0	0		3.2E+08	0.00028	1.232	2.45245	1247	277800
91803	7.2	Jul-89	49					1.1E+07	1.2E-05	0.04484	0.03515	452.7	7731
91803	7.2	Sep-90	63					1.4E+07	1.6E-05	0.05861	0.04845	458.2	9692
91803	7.2	Aug-91	74	7	0	0	7	1.7E+07	2E-05	0.07144	0.05871	530.1	11890
91803	7.2	Sep-92	87	5	0	0	5	2.4E+07	2.5E-05	0.09528	0.07211	1108	17120
91803	7.2	May-94	107	103	0	0	103	3E+07	3.1E-05	0.116	0.09111	1137	20620
91803	7.2	May-95	119	207	7	0	214	3.5E+07	3.6E-05	0.1356	0.10683	1244	24090
91803	7.2	Oct-96	136	364	0	0	364	4.2E+07	4.6E-05	0.1684	0.13889	1252	28590
91803	7.2	May-97	143	557	0	0	557	4.6E+07	4.7E-05	0.1774	0.14409	1416	30950
91803	7.2	Sep-97	147	74	0	0	74	4.8E+07	5.1E-05	0.1902	0.15689	1416	32500
91803	7.2	Jun-98	156	279	11	0	290	5.8E+07	5.7E-05	0.2203	0.16791	2471	40240
120103	12	Dec-96	14	0	0	0	0	55360	8E-08	0.00023	0.00021	0.00024	22.09
120104	18	Dec-96	14	0	0	0	0	182100	5E-07	0.00137	0.00137	0.00137	118.1
120105	7.9	Dec-96	14	0	0	0	0	1340000	1.4E-06	0.00511	0.00532	0.00527	710.5
120106	15	Dec-96	14	0	0	0	0	116200	2.7E-07	0.00077	0.00077	0.00077	68.46
123995	5	Apr-92	197	34	0	0	34	2.4E+10	0.04782	149.3	23.2063	23.68	1.7E+07
123995	5	Mar-94	220	82	0	0	82	2.7E+10	0.05499	171.4	25.9236	26.43	1.9E+07
123995	5	Jan-96	242	215	0	0	215	3.1E+10	0.061	190.6	28.4485	29.02	2.1E+07
123995	5	Jan-96	243	72	0	0	72	3.1E+10	0.06112	191.1	28.5485	29.14	2.1E+07
123997	3.1	Aug-90	195					1.4E+09	0.00887	22.07	22.2806	22.26	1845000

Table E-2 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS-1 Model.

Section	Total AC Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Med	High	Total	1.0,2.5	1.2,0.8	1.2,1.5 (Ave Thermal)	1.2,1.5 (No Thermal)	1.2,1.5 (max Thermal)	1.2,2.5
123997	3.1	Oct-91	209					1.5E+09	0.00964	24.15	24.3889	24.35	2037000
123997	3.1	Mar-93	226					1.7E+09	0.01041	26.24	26.4973	26.48	2241000
123997	3.1	Mar-94	238					1.8E+09	0.01137	28.69	28.9669	28.97	2450000
124105	2.3	Apr-89	53	0	0	0	0	5.2E+09	0.04751	121	121.841	1699	1.1E+07
124105	2.3	Oct-91	83	0	0	0	0	8.3E+09	0.07512	193.7	195.006	1772	1.7E+07
124105	2.3	Mar-93	100	0	0	0	0	9.8E+09	0.08432	220.4	221.872	3488	2E+07
124106	8.2	Apr-89	21					5.5E+07	8.9E-05	0.2701	0.27011	0.2859	28880
124106	8.2	Feb-91	43					1.1E+08	0.00017	0.5271	0.52741	0.5521	59420
124106	8.2	Jul-91	48	0	0	0	0	1.3E+08	0.00019	0.5906	0.59074	0.6155	66670
124106	8.2	Mar-94	80	10	0	0	10	2.2E+08	0.00029	0.9464	0.9466	0.9853	111600
124106	8.2	Jan-97	114	50	0	0	50	3.1E+08	0.0004	1.323	1.32289	1.383	158800
124107	2.7	Dec-89	75	0	0	0	0	2.2E+08	0.00107	3.197	2.91944	3.2	333900
124107	2.7	Feb-91	89	261	0	0	261	2.7E+08	0.00125	3.789	3.46079	3.791	402700
124107	2.7	Jul-91	94	343	0	0	343	3E+08	0.00135	4.097	3.74252	4.099	434500
124107	2.7	Mar-93	114	18	0	0	18	3.7E+08	0.00164	5.032	4.59598	5.038	542900
124107	2.7	Mar-94	126	37	13	0	51	4.3E+08	0.00186	5.717	5.22019	5.723	618500
124107	2.7	Jan-96	148	67	0	0	67	5.3E+08	0.00222	6.908	6.31579	6.915	760200
124107	2.7	Mar-97	162	0	0	0		6E+08	0.00247	7.726	7.06429	7.734	856800
124108	9.9	Apr-89	35	0	0	0	0	2267000	1.4E-05	0.02829	0.028	82.68	1809
124108	9.9	Jan-91	56	0	0	0	0	3767000	2.6E-05	0.05034	0.04996	82.7	3127
124108	9.9	Oct-91	65	0	0	0	0	4441000	2.8E-05	0.0565	0.05613	82.71	3620
124108	9.9	Mar-94	94	7	0	0	7	6744000	4E-05	0.0822	0.08136	192.9	5454
124108	9.9	Aug-94	99	0	0	0	0	7213000	4.2E-05	0.08632	0.08548	192.9	5799
124108	9.9	Jan-96	116	0	0	0	0	8382000	4.5E-05	0.09494	0.09409	192.9	6575
124135	1.4	Dec-89	227	99	199	0	298	4.3E+11	3.292	10930	8453.58	13180	1.4E+09
124135	1.4	Jan-91	240	412	271	0	683	4.6E+11	3.438	11460	8863.56	13700	1.5E+09
131031	11.1	Apr-91	119	0	0	0	0	7227000	2.2E-05	0.05482	0.01846	1.816	4477
131031	11.1	Jul-92	134	0	0	0	0	9483000	2.9E-05	0.07178	0.02577	2.411	5892
131031	11.1	Jan-93	140	0	0	0	0	1E+07	3.2E-05	0.07759	0.02839	2.749	6361
131031	11.1	Apr-94	155	0	0	0	0	1.2E+07	3.7E-05	0.09148	0.0325	2.781	7543
131031	11.1	Oct-94	161	0	0	0	0	1.4E+07	4.1E-05	0.1019	0.03429	2.793	8467
131031	11.1	Aug-95	171	0	0	0	0	1.6E+07	4.7E-05	0.1164	0.03676	3.263	9658
131031	11.1	Jan-96	176	4	0	0	4	1.6E+07	4.8E-05	0.1201	0.03729	4.185	10020
131031	11.1	Apr-96	179	23	0	0	23	1.6E+07	4.8E-05	0.1204	0.03734	4.222	10060
134111	8.7	Mar-89	101	27	0	0	27	7413000	2.8E-05	0.0701	0.06996	0.5428	5982
134111	8.7	Mar-91	125	291	0	0	291	1.1E+07	4E-05	0.1037	0.10347	1.12	9018
134111	8.7	Feb-92	136	477	0	0	477	1.3E+07	4.6E-05	0.1203	0.12013	1.205	10520
134112	15.9	May-89	144	0	0	0	0	2.8E+07	0.00029	0.5896	0.5727	0.5902	36230
134112	15.9	Feb-91	165	17	0	0	17	3.6E+07	0.00035	0.7357	0.7086	0.7357	45940
134112	15.9	Apr-91	167	0	0	0	0	3.6E+07	0.00035	0.7364	0.7093	0.7364	46000

Table E-2 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS-1 Model.

Section	Total AC Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Med	High	Total	1.0,2.5	1.2,0.8	1.2,1.5 (Ave Thermal)	1.2,1.5 (No Thermal)	1.2,1.5 (max Thermal)	1.2,2.5
134112	15.9	Feb-94	201	0	0	0	0	4.9E+07	0.00046	0.9886	0.9495	0.9883	62900
134112	15.9	Oct-94	209	0	0	0	0	5.3E+07	0.00049	1.05	1.009	1.049	67350
134112	15.9	Jan-96	224	0	0	0	0	5.9E+07	0.00055	1.179	1.134	1.179	75630
134112	15.9	Feb-97	237	0	0	0	0	6.5E+07	0.0006	1.289	1.241	1.29	82920
134112	15.9	Apr-98	251	0	0	0	0	7.1E+07	0.00065	1.406	1.355	1.407	90780
134113	15.2	May-89	144	0	0	0	0	6.4E+07	0.00082	1.564	1.488	1.567	85630
134113	15.2	Feb-91	165	0	0	0	0	7.8E+07	0.00096	1.859	1.772	1.86	103800
134113	15.2	Apr-91	167	0	0	0	0	7.8E+07	0.00096	1.861	1.773	1.862	103900
134113	15.2	Feb-94	201	0	0	0	0	1E+08	0.00121	2.394	2.289	2.395	136600
134113	15.2	Oct-94	209	0	0	0	0	1.1E+08	0.00127	2.533	2.424	2.535	145600
134113	15.2	Jan-96	224	0	0	0	0	1.2E+08	0.00139	2.783	2.667	2.786	160400
134113	15.2	Feb-97	237	31	0	0	31	1.3E+08	0.0015	3.006	2.884	3.012	173900
134113	15.2	Apr-98	251	37	0	0	37	1.4E+08	0.00162	3.259	3.114	3.265	189000
161001	3.7	Jul-89	192	155	0	0	155	1.1E+10	0.00975	46.6	7.63222	3275	1.1E+07
161001	3.7	Aug-90	205	193	0	0	193	1.2E+10	0.01132	53.63	8.4377	3295	1.2E+07
161001	3.7	Jun-93	239	78	0	0	78	1.6E+10	0.01402	67.52	10.6735	4261	1.6E+07
161001	3.7	Aug-94	253	199	0	0	199	1.7E+10	0.01533	73.38	11.8764	5395	1.7E+07
161001	3.7	May-95	262	183	2	0	185	1.9E+10	0.01635	79.41	12.3568	5408	1.9E+07
161001	3.7	Jul-97	288	67	63	44	175	2.2E+10	0.01953	93.85	14.5782	5546	2.2E+07
161001	3.7	Sep-98	302	0	159	5	164	2.3E+10	0.02053	99.04	15.9616	7496	2.3E+07
161009	10.4	Sep-89	180					1.3E+07	1.8E-05	0.05175	0.03825	543.1	8271
161009	10.4	Jul-90	190					1.4E+07	1.8E-05	0.0536	0.04016	630.9	8473
161009	10.4	Jul-92	214	0	0	0	0	1.8E+07	2.2E-05	0.06714	0.04876	636.4	10980
161009	10.4	Oct-93	229	8	0	0	8	1.9E+07	2.5E-05	0.07463	0.05649	637.3	11650
161009	10.4	Jun-96	261	1	0	0	1	2.2E+07	2.9E-05	0.08482	0.06562	850.2	13110
161009	10.4	Jul-97	274	0	0	0	0	2.8E+07	3.4E-05	0.1023	0.07489	852.2	16750
161021	5.9	Sep-89	48					2.9E+07	2E-05	0.07713	0.05469	325.1	18040
161021	5.9	Oct-90	61	0	0	0	0	4E+07	2.6E-05	0.1025	0.06904	470.8	24560
161021	5.9	Aug-91	71	0	0	0	0	4.5E+07	2.9E-05	0.1139	0.07943	592.2	27170
161021	5.9	Aug-93	95	0	0	0	0	6.3E+07	4E-05	0.1615	0.10779	788.5	39280
161021	5.9	Sep-95	120	0	0	0	0	8.2E+07	5.1E-05	0.2067	0.13673	976.4	50530
161021	5.9	Jun-96	129	5	0	0	5	8.8E+07	5.3E-05	0.2163	0.14514	1115	53240
161021	5.9	Jul-97	142	0	0	0	0	9.4E+07	5.8E-05	0.2345	0.16207	1178	56930
169034	9.2	Jul-89	10					1394000	2.3E-06	0.00586	0.00513	1.666	626.1
169034	9.2	Aug-90	23					4158000	9.5E-06	0.02237	0.01913	26.25	2144
169034	9.2	Jun-93	57	12	0	0	12	1.1E+07	1.6E-05	0.04369	0.03431	69.65	5582
169034	9.2	Aug-94	71	146	0	0	146	1.3E+07	2.1E-05	0.05505	0.04423	71.18	6709
169034	9.2	May-95	80					1.5E+07	2.1E-05	0.05755	0.0457	95.76	7296
169034	9.2	Jul-97	106	217	0	0	217	2.1E+07	2.8E-05	0.07888	0.06108	135.1	10520
169034	9.2	Sep-98	120	156	52	18	226	2.3E+07	3.2E-05	0.08769	0.06866	139.2	11550

Table E-2 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS-1 Model.

Section	Total AC Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Med	High	Total	1.0,2.5	1.2,0.8	1.2,1.5 (Ave Thermal)	1.2,1.5 (No Thermal)	1.2,1.5 (max Thermal)	1.2,2.5
201009	11.1	Aug-88	44	0	0	0	0	4014000	2.9E-06	0.0106	0.00362	75.7	2482
201009	11.1	May-89	53	11	0	0	11	5067000	3.2E-06	0.01216	0.00375	123.5	3013
201009	11.1	Dec-90	72	210	5	0	215	7804000	4.6E-06	0.01843	0.00539	173.5	4703
201009	11.1	Oct-91	82	6	1	0	7	8019000	5.1E-06	0.01966	0.0063	183.1	4813
201009	11.1	Apr-93	100	9	0	0	9	9891000	5.8E-06	0.02322	0.00683	216.6	5939
201009	11.1	Apr-95	124	16	28	0	43	1.3E+07	7.6E-06	0.031	0.00885	317.7	8039
201009	11.1	Apr-96	136	0	0	0		1.4E+07	7.8E-06	0.03165	0.00933	329.5	8116
201009	11.1	Jan-99	168	0	0	0		1.6E+07	9.5E-06	0.03829	0.01171	424.6	9696
251003	6.6	Aug-89	180	758	0	0	758	6.7E+07	6E-05	0.2707	0.1645	220.2	56490
251003	6.6	Sep-90	193	691	0	0	691	7.4E+07	6.5E-05	0.2956	0.17986	255.8	61890
251003	6.6	Aug-91	204	556	1	0	557	7.9E+07	7E-05	0.3154	0.19253	259.8	66040
251003	6.6	Sep-92	217	600	0	0	600	8.5E+07	7.6E-05	0.3427	0.20963	264.4	71430
251003	6.6	Oct-95	254	563	0	0	563	1.1E+08	9.3E-05	0.4254	0.25845	348.1	89640
251003	6.6	Oct-96	266	39	0	0	39	1.1E+08	9.9E-05	0.4514	0.27498	353	94960
251003	6.6	Jun-98	286	32	9	0	41	1.3E+08	0.00011	0.5005	0.30278	421.4	106100
251004	9.6	Aug-89	178	0	0	0	0	1.2E+07	3E-05	0.08499	0.05861	436.7	9509
251004	9.6	Sep-90	191	19	0	0	19	1.3E+07	3.3E-05	0.09424	0.06524	437.7	10430
251004	9.6	Aug-91	202	16	0	0	16	1.3E+07	3.6E-05	0.102	0.07104	478.8	11170
251004	9.6	Sep-92	215	0	0	0		1.5E+07	4E-05	0.1143	0.08002	488	12380
251004	9.6	Oct-95	252	0	0	0		2E+07	5.2E-05	0.1485	0.10287	619.4	16450
251004	9.6	Jun-97	272	3	0	0	3	2.2E+07	5.8E-05	0.1658	0.11557	681.7	18170
251004	9.6	Jun-98	284	3	0	0	3	2.6E+07	6.4E-05	0.1837	0.12579	776.5	20820
261001	2.2	Jul-88	203	0	0	0	0	5.4E+08	0.00293	8.298	8.22075	375.6	888800
261001	2.2	Sep-89	217	16	0	0	16	5.8E+08	0.00317	8.952	8.86858	376.3	956000
261001	2.2	Jul-90	227	24	0	0	24	6E+08	0.00326	9.243	9.15617	376.6	991600
261001	2.2	Jul-91	239	0	0	0		6.3E+08	0.00343	9.718	9.62587	377.1	1043000
261001	2.2	Sep-91	241	51	0	0	51	6.4E+08	0.00348	9.869	9.77613	377.2	1057000
261001	2.2	Sep-92	253	0	0	0		6.7E+08	0.00363	10.28	10.1901	377.6	1104000
261001	2.2	Jun-93	262	23	0	0	23	6.9E+08	0.00372	10.57	10.4687	377.9	1138000
261001	2.2	Jun-93	263	0	0	0		6.9E+08	0.00376	10.67	10.5683	378	1147000
261001	2.2	May-95	285	9	0	0	9	7.5E+08	0.00403	11.45	11.3345	378.8	1234000
261001	2.2	Jul-96	299	5	0	0	5	7.9E+08	0.00425	12.08	11.9614	379.4	1301000
261004	4.2	Sep-89	51	321	0	0	321	2.6E+08	0.00019	0.9398	0.32643	2306	243100
261004	4.2	Jul-90	61	451	0	0	451	3.1E+08	0.00022	1.131	0.40006	3054	295800
271018	4.4	Apr-89	124	0	0	0	0	1.2E+09	0.0006	3.559	1.45779	7468	1067000
271018	4.4	Jun-89	126					1.2E+09	0.00061	3.598	1.49785	7468	1074000
271018	4.4	Oct-90	142					1.3E+09	0.0007	4.083	1.77963	7858	1210000
271018	4.4	Jun-93	174	41	1	0	41	1.9E+09	0.00101	6.105	2.36084	10660	1849000
271018	4.4	Jul-93	176	7	51	0	57	1.9E+09	0.00103	6.154	2.41109	10660	1853000
271018	4.4	Mar-94	183	58	39	0	98	2.2E+09	0.00113	6.885	2.48849	12720	2099000

Table E-2 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS-1 Model.

Section	Total AC Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Med	High	Total	1.0,2.5	1.2,0.8	1.2,1.5 (Ave Thermal)	1.2,1.5 (No Thermal)	1.2,1.5 (max Thermal)	1.2,2.5
271018	4.4	Aug-94	188	131	0	0	131	2.2E+09	0.00117	7.022	2.63108	12720	2125000
271087	15.7	Oct-91	154	0	0	0	0	5.6E+08	0.00026	1.678	0.1206	27820	514900
271087	15.7	May-93	173	8	0	0	8	6.7E+08	0.00031	2	0.128	31660	617400
271087	15.7	Oct-94	190	24	0	0	24	7.5E+08	0.00034	2.221	0.1434	35830	685300
271087	15.7	Jun-96	210	25	0	0	25	7.9E+08	0.00036	2.34	0.1554	38210	721100
291008	11.4	Feb-92	70	0	0	0	0	3210000	8.1E-07	0.00585	0.00015	66.32	2087
291008	11.4	Mar-93	83	58	3	0	61	3220000	8.2E-07	0.00588	0.00017	67.35	2090
291008	11.4							3220000	8.2E-07	0.00588	0.00017	67.35	2091
291008	11.4	Apr-96	120	130	0	0	130	6511000	1.6E-06	0.01198	0.00024	134.6	4300
291008	11.4	Feb-00	152	26	0	0	26	6883000	1.7E-06	0.01247	0.00032	148.6	4449
307088	4.9	Sep-89	100	0	0	0	0	4.6E+08	0.00036	1.672	0.65907	2696	398600
307088	4.9	May-91	120	4	12	0	16	5.8E+08	0.00045	2.091	0.80108	3631	500600
308129	3.2	Oct-89	17					6.9E+07	3.1E-05	0.173	0.28791	198.7	53760
308129	3.2	Jul-91	38					3.3E+08	0.00014	0.8541	0.71093	442	270100
308129	3.2	Jul-92	50	0	0	0	0	4.6E+08	0.00018	1.162	0.91598	843.3	380800
308129	3.2	Aug-93	63	0	0	0	0	5.4E+08	0.00021	1.357	1.08169	1095	446000
308129	3.2	Dec-93	67	0	0	0	0	5.7E+08	0.00022	1.415	1.11825	1291	466600
308129	3.2	Mar-94	70	0	0	0	0	6.7E+08	0.00025	1.655	1.19097	1359	553400
308129	3.2	Oct-94	77	0	0	0	0	7.7E+08	0.00031	1.993	1.24144	1359	642500
308129	3.2	Feb-95	81	0	0	0	0	8.6E+08	0.00034	2.182	1.30423	1389	712000
308129	3.2	May-95	84	0	0	0	0	8.7E+08	0.00034	2.199	1.34754	1389	717900
308129	3.2	Jun-96	97	0	0	0	0	1E+09	0.00039	2.538	1.53551	1838	838100
308129	3.2	Oct-96	101	0	0	0	0	1E+09	0.00039	2.556	1.55895	1838	841900
308129	3.2	Jan-97	104	0	0	0	0	1.1E+09	0.0004	2.642	1.61896	2036	874400
308129	3.2	Mar-97	106	0	0	0	0	1.1E+09	0.00041	2.681	1.68016	2160	888700
308129	3.2	Aug-97	111	0	0	0	0	1.1E+09	0.00042	2.718	1.71791	2160	895100
308129	3.2	Oct-97	113	0	0	0	0	1.1E+09	0.00042	2.727	1.73182	2160	896900
321020	7	Jul-91	86	34	0	0	34	7.8E+07	5.9E-05	0.236	0.1702	117.5	47610
321020	7	Aug-93	111	138	0	0	138	1.2E+08	8.3E-05	0.3443	0.23427	252.3	73540
321020	7	Sep-94	123	29	20	0	49	1.3E+08	9.4E-05	0.3874	0.26811	261.6	82030
321020	7	Apr-95	131	242	0	0	242	1.4E+08	9.8E-05	0.4065	0.28463	262.2	86690
321020	7	Jun-97	157	9	0	0		1.8E+08	0.00013	0.5131	0.36794	263.2	106500
321020	7	Jun-98	169	0	0	0		2.1E+08	0.00014	0.5952	0.40581	512.3	130000
341031	7.3	Apr-92	224	333	1	0	333	3.8E+08	0.00089	2.737	2.809	338.3	330800
341031	7.3	Feb-93	234	322	31	3	356	4.1E+08	0.00098	3.008	3.08812	343.1	361700
341031	7.3	Oct-95	266	0	352	170	522	5.5E+08	0.00132	4.041	4.16173	346.8	485800
341031	7.3	Nov-95	267	232	30	0	261	5.5E+08	0.00132	4.048	4.16843	357.8	487700
341033	7.4	Apr-92	211	52	2	0	54	9256000	8.7E-06	0.03193	0.07771	0.1925	5286
341033	7.4	Feb-93	221	32	11	0	44	9711000	9.2E-06	0.03369	0.0823	0.1955	5552
341033	7.4	Nov-95	254	55	0	0	55	1.1E+07	1.1E-05	0.03925	0.09711	0.2147	6441

Table E-2 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS-1 Model.

Section	Total AC Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Med	High	Total	1.0,2.5	1.2,0.8	1.2,1.5 (Ave Thermal)	1.2,1.5 (No Thermal)	1.2,1.5 (max Thermal)	1.2,2.5
341033	7.4	Jul-97	274	260	0	0	260	1.2E+07	1.2E-05	0.04246	0.10401	0.2308	7073
341034	11.1	Oct-89	48	0	0	0	0	5956000	2E-05	0.04772	0.04661	36.45	3906
341034	11.1	Sep-90	59	0	0	0	0	7416000	2.4E-05	0.05974	0.05858	37.09	4880
341034	11.1	Apr-92	78	0	0	0	0	9195000	2.8E-05	0.07036	0.0688	70.8	5894
341034	11.1	Feb-93	88	0	0	0	0	1.1E+07	3.3E-05	0.0818	0.0802	72.46	6876
341034	11.1	Nov-95	121	3	0	0	3	1.7E+07	4.7E-05	0.12	0.1174	83.91	10400
341034	11.1	Jul-97	141	0	15	0	15	2E+07	5.5E-05	0.1405	0.1375	84.58	12260
350101	7.2	May-97	19	0	0	0	0	7.8E+07	0.00027	0.7078	0.71574	2.548	66490
350102	4.8	May-97	19	0	0	0	0	1.4E+08	0.00019	0.6728	0.70497	3.805	101100
350103	12.5	May-97	19	0	0	0	0	6772	6.5E-09	1.4E-05	1.1E-05	0.249	1.542
350104	19.2	May-97	19	0	0	0	0	599900	5.8E-06	0.01064	0.01064	0.3927	504.7
350105	9.9	May-97	19	0	0	0	0	1172000	8.9E-06	0.01669	0.01668	0.4905	832.9
350106	15.6	May-97	19	0	0	0	0	93060	8.3E-07	0.00146	0.00145	0.4271	64.98
351005	8.9	Oct-89	73	0	0	0	0	7422000	8.5E-06	0.02665	0.02382	840.8	3850
351005	8.9	Mar-91	90	0	0	0	0	1E+07	1E-05	0.03279	0.02762	1303	5194
351005	8.9	Oct-92	109	0	0	0	0	1.3E+07	1.3E-05	0.04225	0.03619	1596	6539
351005	8.9	Feb-94	125	0	0	0	0	1.6E+07	1.5E-05	0.05073	0.04289	2490	8009
351005	8.9	Mar-95	138	0	0	0	0	2E+07	1.9E-05	0.06356	0.05231	2721	10420
351005	8.9	Apr-97	163	0	0	0	0	2.5E+07	2.3E-05	0.07845	0.06584	3742	12660
351022	6.3	Oct-89	37	0	0	0	0	2E+07	1.7E-05	0.0649	0.03548	506.9	12350
351022	6.3	Mar-91	54	0	0	0	0	3.1E+07	2.6E-05	0.09779	0.05438	599.4	18400
351022	6.3	Oct-92	73	0	0	0	0	5.3E+07	4.3E-05	0.1659	0.08748	2235	32370
351022	6.3	Feb-94	89	0	0	0	0	6.7E+07	5.4E-05	0.2103	0.11217	2419	41070
351022	6.3	Mar-95	102	0	0	0	0	8.1E+07	6.6E-05	0.2549	0.13884	2519	48970
351022	6.3	Apr-97	127	0	0	0	0	1.2E+08	9.5E-05	0.3726	0.19558	4293	72950
351112	6.3	Dec-89	67					2.6E+08	0.00043	1.272	1.22121	841.6	181200
351112	6.3	Jan-91	80					3.1E+08	0.00048	1.48	1.42738	842.5	215500
351112	6.3	Mar-91	82	0	0	0	0	3.2E+08	0.00049	1.509	1.45631	842.6	221600
351112	6.3	Jan-93	104	0	0	0	0	4.1E+08	0.00059	1.879	1.80407	1301	281400
351112	6.3	Feb-94	117	0	0	0	0	4.6E+08	0.00065	2.091	2.01327	1303	315400
351112	6.3	Oct-94	125	0	0	0	0	4.9E+08	0.0007	2.253	2.17168	1304	337200
351112	6.3	Mar-95	130	14	0	0	14	5.2E+08	0.00072	2.321	2.22852	1312	354800
351112	6.3	Apr-95	131	0	0	0	0	5.2E+08	0.00072	2.341	2.24803	1312	358200
351112	6.3	Jun-95	133	0	0	0	0	5.3E+08	0.00073	2.384	2.29074	1312	363900
351112	6.3	Nov-96	150	0	0	0	0	6E+08	0.00082	2.681	2.582	1313	410000
351112	6.3	Apr-97	155	0	0	0	0	6.2E+08	0.00083	2.734	2.63514	1313	422200
351112	6.3	Sep-97	160	0	0	0	0	6.4E+08	0.00086	2.843	2.74142	1313	435200
371024	4.8	Nov-89	109					2.4E+07	2.8E-05	0.1073	0.3606	0.1483	18680
371024	4.8	Mar-91	125					2.8E+07	3.1E-05	0.1229	0.42311	0.1805	21920
371024	4.8	Apr-92	138	3	0	0	3	3.2E+07	3.5E-05	0.1384	0.48133	0.2005	24860
371802	4.5	Mar-91	66					5.2E+08	0.00288	7.835	10.3732	10.69	780600

Table E-2 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS-1 Model.

Section	Total AC Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Med	High	Total	1.0,2.5	1.2,0.8	1.2,1.5 (Ave Thermal)	1.2,1.5 (No Thermal)	1.2,1.5 (max Thermal)	1.2,2.5
371802	4.5	Oct-92	85	28	0	0	28	6.9E+08	0.00383	10.41	14.0077	14.48	1028000
371802	4.5	Apr-94	103	0	0	0		8.3E+08	0.00444	12.19	16.5856	17.22	1227000
371802	4.5	Jul-95	118	41	0	0	41	9.5E+08	0.00523	14.25	19.5247	20.36	1417000
371802	4.5	Apr-96	127	0	0	0		1E+09	0.0055	15.08	20.7195	21.61	1513000
371992	2.4	Mar-91	14					1.5E+08	0.00084	2.264	2.23258	2.642	214800
371992	2.4	Oct-92	33	22	0	0	22	4.3E+08	0.00291	7.503	7.3743	8.15	666900
371992	2.4	Apr-94	51	0	0	0	0	6.9E+08	0.00438	11.41	11.0792	30.26	1035000
371992	2.4	Feb-96	73	0	0	0	0	1.1E+09	0.00679	17.84	17.1456	51.11	1632000
404087	10.1	Jan-90	43	0	0	0	0	423600	3.8E-06	0.00761	0.00227	0.2893	421.9
404087	10.1	Oct-91	64	0	0	0	0	667400	5.5E-06	0.01127	0.00347	0.2989	650.3
404087	10.1	Nov-92	77	31	0	0	31	795700	6.4E-06	0.01317	0.00408	0.4075	769.9
404087	10.1	Feb-93	80	35	0	0	35	795700	6.4E-06	0.01317	0.00408	0.4078	769.9
404087	10.1	Nov-94	101	143	0	0	143	1053000	8E-06	0.01674	0.00526	0.7112	1003
404087	10.1	Feb-95	104	112	0	0	112	1053000	8E-06	0.01674	0.00526	0.7156	1003
404087	10.1	Aug-95	110	0	159	0	159	1253000	9.3E-06	0.01974	0.00618	0.7241	1193
404087	10.1	Jun-97	132	10	0	0	10	1556000	1.1E-05	0.0239	0.00765	0.8968	1468
404163	11.5	Jan-90	34					160400	6.6E-07	0.00138	0.00136	0.1047	85.81
404163	11.5	Mar-91	48					215500	8.4E-07	0.0018	0.00178	0.2743	114.6
404163	11.5	Oct-91	55	0	0	0	0	252700	9.5E-07	0.00204	0.00202	0.2747	132.4
404163	11.5	Nov-92	68	0	0	0	0	326000	1.2E-06	0.00264	0.00261	0.311	172.8
404163	11.5	Mar-93	72	7	0	0	7	330900	1.2E-06	0.00264	0.00261	0.3802	173.8
404163	11.5	Nov-94	92	0	0	0	0	428200	1.5E-06	0.00333	0.00329	0.3824	223.9
404163	11.5	Apr-96	109	0	0	0	0	466100	1.6E-06	0.00355	0.00351	0.5878	241
404163	11.5	Aug-97	125	45	8	0	53	601500	2E-06	0.00456	0.00451	0.6583	313.1
404163	11.5	Jan-99	141	6	9	0	15	663200	2.2E-06	0.00494	0.00488	0.7633	342.2
404165	8.1	Jan-90	68					2.9E+07	5.1E-05	0.1386	0.13477	13.03	15610
404165	8.1	Mar-91	82					3.5E+07	5.8E-05	0.1601	0.15615	13.13	18470
404165	8.1	Oct-91	89	4	0	0	4	3.8E+07	6.5E-05	0.1797	0.17558	13.15	20750
404165	8.1	Nov-92	102	5	0	0	5	4.4E+07	7E-05	0.1979	0.19247	20.42	23620
404165	8.1	Mar-93	106	19	0	0	19	4.5E+07	7E-05	0.1987	0.19317	21.07	23880
404165	8.1	Oct-94	125	9	0	0	9	5.5E+07	8.7E-05	0.2487	0.24179	23.99	29600
404165	8.1	Nov-94	126	16	0	0	16	5.6E+07	8.7E-05	0.249	0.24209	24.06	29680
404165	8.1	Apr-95	131	24	0	0	24	5.7E+07	8.8E-05	0.2513	0.24441	24.65	30220
404165	8.1	Jun-95	133	25	0	0	25	5.8E+07	8.9E-05	0.2562	0.2492	24.66	30920
404165	8.1	Apr-96	143	25	0	0	25	6.4E+07	9.5E-05	0.2738	0.26595	27.61	33490
404165	8.1	Nov-96	150	60	0	0	60	6.8E+07	0.0001	0.2934	0.28532	27.64	35790
404165	8.1	May-97	156	26	0	0	26	7E+07	0.0001	0.297	0.28884	27.69	36510
404165	8.1	Sep-97	160	24	0	0	24	7.2E+07	0.00011	0.3099	0.30157	27.71	38050
421599	12.3	Aug-89	25					2544000	3.6E-06	0.01046	0.00867	537.3	1535
421599	12.3	Sep-90	38					4109000	4.7E-06	0.01513	0.01142	768.5	2454

Table E-2 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS-1 Model.

Section	Total AC Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Med	High	Total	1.0,2.5	1.2,0.8	1.2,1.5 (Ave Thermal)	1.2,1.5 (No Thermal)	1.2,1.5 (max Thermal)	1.2,2.5
421599	12.3	Mar-93	68	0	0	0	0	8243000	8.5E-06	0.02869	0.01963	1580	4870
421599	12.3	Sep-94	86	0	0	0	0	1E+07	1.1E-05	0.03732	0.02793	1876	6185
421599	12.3	Jun-95	95	8	0	0	8	1.2E+07	1.2E-05	0.04181	0.0295	1968	7106
421599	12.3	Jul-96	108	4	0	0	4	1.2E+07	1.4E-05	0.0449	0.0354	2001	7262
421599	12.3	Mar-98	128	2	0	0	2	1.6E+07	1.9E-05	0.05922	0.04492	2938	9532
451011	3.2	Mar-92	69	0	0	0	0	8.2E+08	0.00336	8.849	8.70677	11.28	850000
451011	3.2	Oct-92	76	0	0	0	0	9.2E+08	0.00386	10.16	9.97444	12.6	964600
451011	3.2	Jun-93	84	0	0	0	0	1E+09	0.00395	10.5	10.3122	13.24	1024000
451011	3.2	Jan-96	115	16	0	0	16	1.4E+09	0.00548	14.7	14.4172	18.32	1439000
451011	3.2	Jun-97	132	0	0	0	0	1.6E+09	0.0061	16.47	16.1578	20.82	1631000
451011	3.2	Feb-99	150	0	0	0	0	1.8E+09	0.00688	18.69	18.3355	23.74	1861000
473104	1.3	Aug-89	39					2E+08	0.00164	4.852	15.1196	4.874	597100
473104	1.3	Nov-89	42					2.1E+08	0.00169	5.062	16.3095	5.085	629700
473104	1.3	May-91	60					3.2E+08	0.00205	6.576	22.0194	8.09	918200
473104	1.3	Aug-91	63					3.3E+08	0.00214	6.825	24.0893	8.339	942900
473104	1.3	Oct-92	77					4E+08	0.00248	8.06	31.1491	9.577	1139000
473104	1.3	Aug-93	87					4.7E+08	0.00277	9.194	36.549	10.73	1331000
473104	1.3	Nov-95	114					6.9E+08	0.00364	12.62	53.2085	16.05	1927000
473104	1.3	Oct-96	125					7.9E+08	0.00413	14.43	61.9083	17.86	2220000
480001	2.4	Apr-89	1					1.6E+07	0.00014	0.3351	0.45085	0.3375	25690
480001	2.4	Oct-90	19					4.1E+08	0.00654	12.52	16.9191	12.63	759700
480001	2.4	May-91	26	0	0	0	0	5.6E+08	0.00701	14	18.81	14.2	945100
480001	2.4	Feb-93	47	0	0	0	0	1.1E+09	0.01378	27.92	37.3639	28.72	1921000
480001	2.4	Apr-93	49	0	0	0	0	1.2E+09	0.01393	28.42	37.9942	29.23	1985000
480001	2.4	Feb-95	71	0	0	0	0	1.9E+09	0.0196	41.63	55.5239	42.78	3082000
480001	2.4	Mar-95	72	0	0	0	0	2E+09	0.01964	41.82	55.7504	42.98	3115000
480001	2.4	May-97	98	34	0	0	34	3E+09	0.02848	61.8	82.0942	63.89	4713000
480001	2.4	Mar-98	108	34	0	0	34	3.5E+09	0.03213	70.22	93.1241	72.6	5431000
481060	7.5	Jun-90	52	0	0	0	0	4.5E+08	0.00109	3.118	3.10921	3.631	323500
481060	7.5	Feb-91	60	0	0	0	0	5.1E+08	0.00125	3.583	3.57195	4.143	373300
481060	7.5	Apr-91	62	0	0	0	0	5.3E+08	0.00127	3.649	3.63897	4.241	382300
481060	7.5	Mar-92	73	12	0	0	12	6.4E+08	0.0015	4.38	4.37279	5.066	463700
481060	7.5	Feb-93	84	19	0	0	19	7.7E+08	0.00177	5.186	5.18369	5.948	552900
481060	7.5	Mar-93	85	23	0	0	23	7.8E+08	0.00178	5.219	5.21719	5.993	557900
481060	7.5	Oct-94	104	14	0	0	14	1E+09	0.00229	6.79	6.80882	7.831	731200
481060	7.5	Feb-95	108	28	0	0	28	1E+09	0.0023	6.83	6.85238	7.925	738400
481060	7.5	Mar-95	109	0	0	0		1E+09	0.00231	6.85	6.87249	7.966	741400
481060	7.5	Mar-95	112	14	0	0	14	1.1E+09	0.0024	7.163	7.19081	8.296	777100
481060	7.5	Jun-95	134	8	0	0	8	1.4E+09	0.00295	8.891	8.93323	10.21	977400
481060	7.5	Apr-97	137	31	0	0	31	1.4E+09	0.00311	9.37	9.41239	10.69	1029000

Table E-2 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS-1 Model.

Section	Total AC Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Med	High	Total	1.0,2.5	1.2,0.8	1.2,1.5 (Ave Thermal)	1.2,1.5 (No Thermal)	1.2,1.5 (max Thermal)	1.2,2.5
481060	7.5	Jul-97	139	31	2	0	33	1.5E+09	0.00324	9.729	9.77428	11.05	1065000
481060	7.5	Sep-97	154	32	0	0	32	1.7E+09	0.00363	11	11.061	12.55	1214000
481077	5.1	Apr-89	88					1.6E+08	0.00013	0.4936	1.37429	14.2	86870
481077	5.1	Nov-91	119	0	0	0	0	2.2E+08	0.00018	0.673	1.87841	16.87	117500
481077	5.1	Oct-92	130	28	0	0	28	2.5E+08	0.00019	0.7419	2.06034	20.22	130100
481077	5.1	May-93	137	124	0	0	124	2.6E+08	0.0002	0.7786	2.1412	20.98	138300
481077	5.1	Oct-94	154	143	0	0	143	3E+08	0.00023	0.886	2.4553	21.55	155800
481077	5.1	Mar-95	159	47	0	0	47	3.1E+08	0.00023	0.914	2.50973	21.89	162500
481077	5.1	Apr-95	160	181	0	0	181	3.1E+08	0.00024	0.9216	2.52839	21.9	163800
481077	5.1	Jun-95	162	181	0	0	181	3.2E+08	0.00024	0.9365	2.57815	21.91	165900
481077	5.1	Aug-95	164	181	0	0	181	3.2E+08	0.00024	0.9488	2.62635	21.93	167000
481077	5.1	Jun-96	174	181	0	0	181	3.4E+08	0.00026	1.01	2.77563	25.25	179200
481077	5.1	May-97	185	228	10	0	238	3.7E+08	0.00028	1.085	2.95911	28.43	194300
481077	5.1	Jul-97	187	300	0	0	300	3.8E+08	0.00028	1.1	3.01198	28.44	196000
481077	5.1	Sep-97	189	276	0	0	276	3.8E+08	0.00029	1.114	3.06174	28.46	197800
481077	5.1	Mar-98	195	281	0	0	281	4E+08	0.00029	1.147	3.12394	29.5	206000
481109	6.5	Jan-90	68					2.8E+08	0.00095	2.676	2.67743	3.037	287000
481109	6.5	Sep-90	76					3.2E+08	0.00111	3.116	3.11657	3.503	332700
481109	6.5	May-91	84	123	0	0	123	3.6E+08	0.00117	3.35	3.35107	3.805	366800
481109	6.5	Feb-93	105	148	0	0	148	4.6E+08	0.00151	4.35	4.35112	4.925	478600
481109	6.5	Jul-93	110	336	0	0	336	5E+08	0.00162	4.667	4.66647	5.25	513000
481109	6.5	Feb-95	129	502	3	0	505	6E+08	0.00191	5.551	5.55212	6.379	617000
481109	6.5	May-95	132	571	0	0	571	6.2E+08	0.00195	5.697	5.69973	6.524	635900
481109	6.5	Aug-96	147	425	0	0	425	7.2E+08	0.00229	6.688	6.68939	7.776	744800
481130	2.7	Apr-89	200	0	0	0	0	1.3E+09	0.02206	43.16	45.702	43.45	2538000
481130	2.7	Oct-90	218	0	0	0	0	1.5E+09	0.02498	49.02	51.9718	49.33	2884000
481130	2.7	Mar-91	223	15	0	0	15	1.5E+09	0.02503	49.2	52.1651	49.54	2908000
481130	2.7	Mar-92	235	35	0	0	35	1.6E+09	0.02644	52.11	55.2309	52.46	3091000
481169	1.1	Feb-90	211					7.1E+10	0.241	950	883.692	884.7	1.6E+08
481169	1.1	Mar-90	212					7.1E+10	0.2419	954.6	887.992	889.1	1.7E+08
481169	1.1	Sep-90	218					7.3E+10	0.2516	987	917.792	918.9	1.7E+08
481169	1.1	Jan-91	222	0	0	0	0	7.5E+10	0.2548	1005	934.892	936	1.7E+08
481169	1.1	Mar-91	224	0	0	0	0	7.6E+10	0.2565	1014	943.592	944.7	1.8E+08
481169	1.1	Jun-91	227	0	0	0	0	7.7E+10	0.2611	1030	958.491	959.7	1.8E+08
481169	1.1	Jan-92	234	0	0	0	0	8E+10	0.27	1065	990.991	992.2	1.8E+08
481169	1.1	Feb-93	247	0	0	0	0	8.5E+10	0.2864	1132	1052.99	1054	2E+08
481169	1.1	Aug-93	253	0	0	0	0	8.7E+10	0.2955	1164	1082.99	1085	2E+08
481169	1.1	Mar-95	272	7	0	0	7	9.5E+10	0.3179	1262	1173.99	1176	2.2E+08
481169	1.1	Jul-95	276	0	0	0	0	9.6E+10	0.3246	1285	1194.99	1197	2.2E+08
481169	1.1	Jul-97	300	0	0	0	0	1.1E+11	0.3562	1412	1313.99	1316	2.5E+08

Table E-2 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS-1 Model.

Section	Total AC Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Med	High	Total	1.0,2.5	1.2,0.8	1.2,1.5 (Ave Thermal)	1.2,1.5 (No Thermal)	1.2,1.5 (max Thermal)	1.2,2.5
481174	4.7	Oct-90	186					1.9E+08	0.00031	0.972	0.82385	0.9385	122300
481174	4.7	Feb-91	190					1.9E+08	0.00031	0.9874	0.83752	0.9522	125100
481174	4.7	Apr-91	192	201	0	0	201	1.9E+08	0.00031	0.9978	0.8466	0.9612	126700
481174	4.7	Mar-92	203	204	0	0	204	2.1E+08	0.00033	1.057	0.89483	1.016	134300
481174	4.7	Feb-93	214	138	0	0	138	2.2E+08	0.00035	1.111	0.93934	1.065	141400
481174	4.7	Mar-93	215	185	0	0	185	2.2E+08	0.00035	1.115	0.94269	1.068	142000
481174	4.7	Feb-95	238	220	10	0	229	2.4E+08	0.00039	1.235	1.04066	1.18	157500
481174	4.7	Mar-95	239	179	0	0	179	2.4E+08	0.00039	1.239	1.04439	1.184	158300
481174	4.7	Jan-96	249	160	0	0	160	2.5E+08	0.0004	1.294	1.08877	1.233	165100
481174	4.7	Apr-97	264	0	0	0		2.7E+08	0.00043	1.373	1.15453	1.306	175900
481174	4.7	Mar-98	275	49	0	0	49	2.8E+08	0.00044	1.425	1.1973	1.357	182800
481178	8.5	Apr-89	10	78	0	0	78	240300	5.7E-06	0.00753	0.00752	0.00757	238.1
481178	8.5	Feb-91	32	61	0	0	61	781200	9.8E-06	0.01472	0.01467	0.01481	594.1
481178	8.5	May-91	33	48	0	0	48	787300	9.8E-06	0.01475	0.0147	0.01484	596.7
481178	8.5	Feb-93	56	44	0	0	44	1340000	1.3E-05	0.0205	0.02042	0.0206	930.9
481178	8.5	Jul-93	61	94	0	0	94	1519000	1.4E-05	0.02231	0.02223	0.02242	1039
481178	8.5	Feb-95	80	92	0	0	92	2024000	1.6E-05	0.02715	0.02705	0.0273	1336
481178	8.5	Mar-95	81	57	0	0	57	2030000	1.6E-05	0.02718	0.02708	0.02733	1338
481183	5.7	Sep-90	188	0	0	0	0	5.7E+08	0.00247	6.625	7.66612	19.42	657800
481183	5.7	Mar-91	194	0	0	0	0	5.8E+08	0.0025	6.72	7.78211	19.78	672700
481183	5.7	Oct-91	201	4	0	0	4	6.6E+08	0.00288	7.7	8.87459	20.54	761800
481183	5.7	Nov-91	202	11	0	0	11	6.6E+08	0.00288	7.713	8.8933	20.57	764400
481183	5.7	Jan-93	216	19	0	0	19	7.6E+08	0.00326	8.774	10.113	21.76	876900
481183	5.7	Jul-93	222	3	0	0	3	8.2E+08	0.00352	9.51	10.966	22.36	951100
481183	5.7	Apr-94	231	3	0	0	3	8.9E+08	0.00376	10.17	11.7106	23.45	1020000
483749	1.8	Oct-90	116	0	0	0	0	8.1E+09	0.07156	177.2	177.013	178.5	1.5E+07
483749	1.8	Apr-91	122	0	0	0	0	8.4E+09	0.07251	180.5	180.311	181.9	1.6E+07
483749	1.8	Aug-91	126	0	0	0	0	8.7E+09	0.07546	187.8	187.607	189.2	1.6E+07
483749	1.8	Mar-92	133	0	0	0	0	9.1E+09	0.0771	193	192.805	194.5	1.7E+07
483749	1.8	Feb-93	144	0	0	0	0	9.8E+09	0.08194	205.9	205.698	207.6	1.8E+07
483749	1.8	Mar-93	145	0	0	0	0	9.9E+09	0.08214	206.6	206.398	208.3	1.8E+07
483749	1.8	Feb-95	168	0	0	0	0	1.1E+10	0.09163	232.2	231.985	234.3	2.1E+07
483749	1.8	Mar-95	169	0	0	0	0	1.1E+10	0.0918	232.8	232.585	234.9	2.1E+07
483749	1.8	Mar-97	193	2	0	0	2	1.3E+10	0.1012	258.8	258.572	261.2	2.3E+07
489005	1.2	Oct-90	50	169	0	0	169	4.1E+10	0.5583	1558	1557.98	1559	1.6E+08
489005	1.2	Mar-91	55	215	0	0	215	4.5E+10	0.5904	1665	1664.97	1665	1.8E+08
489005	1.2	Aug-91	60	223	0	0	223	4.9E+10	0.6375	1804	1803.97	1805	1.9E+08
489005	1.2	Feb-93	78	106	0	0	106	6.4E+10	0.8037	2306	2305.96	2306	2.5E+08
489005	1.2	Apr-93	80	240	0	0	240	6.5E+10	0.8108	2336	2335.96	2337	2.5E+08
489005	1.2	Feb-95	102	169	0	0	169	8.3E+10	0.9938	2896	2895.95	2897	3.2E+08

Table E-2 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS-1 Model.

Section	Total AC Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Med	High	Total	1.0,2.5	1.2,0.8	1.2,1.5 (Ave Thermal)	1.2,1.5 (No Thermal)	1.2,1.5 (max Thermal)	1.2,2.5
489005	1.2	Feb-96	114	274	0	0	274	9.2E+10	1.099	3212	3211.95	3213	3.5E+08
489005	1.2	Jul-96	119	253	0	0	253	9.7E+10	1.131	3323	3322.95	3324	3.7E+08
489005	1.2	Jul-97	131	325	0	0	325	1.1E+11	1.234	3641	3640.94	3641	4.1E+08
489005	1.2	Jul-98	143	278	0	0	278	1.2E+11	1.336	3960	3959.94	3961	4.4E+08
501002	8.5	Aug-89	58					4.5E+07	2.2E-05	0.132	0.01552	1928	37000
501002	8.5	Aug-90	70					5.6E+07	2.7E-05	0.1611	0.01894	2244	45140
501002	8.5	May-94	115	2	0	0	2	1E+08	4.9E-05	0.2977	0.03078	3907	84240
501002	8.5	Aug-94	118	0	0	0	0	1E+08	5E-05	0.3009	0.03276	3909	84680
501002	8.5	Apr-95	126	8	0	0	8	1.1E+08	5.1E-05	0.3091	0.03374	4359	86840
501002	8.5	Oct-96	144	16	0	0	16	1.4E+08	6.7E-05	0.4096	0.04065	4769	114800
501002	8.5	May-97	151	66	125	0	191	1.4E+08	6.7E-05	0.4105	0.04155	4776	115000
501002	8.5	Oct-97	156	10	5	0	14	1.4E+08	7.1E-05	0.4295	0.0446	4959	119400
501002	8.5	Jun-98	164	10	26	0	36	1.5E+08	7.2E-05	0.4321	0.04651	4975	119800
501004	8	Apr-93	102	34	11	0	44	3.5E+07	1.2E-05	0.08733	0.00088	1173	30790
501004	8	Oct-95	132	8	4	0	12	4.3E+07	1.4E-05	0.1027	0.00145	1512	35960
501004	8	Nov-97	157	7	3	0	9	6.4E+07	2E-05	0.1511	0.002	2070	52970
511002	5.7	Apr-89	115	9	42	59	110	4.1E+08	0.00067	2.461	2.14831	42.54	392600
511023	10.1	Oct-89	107	0	0	0	0	2.1E+07	5.8E-05	0.1507	0.1504	1.158	13020
511023	10.1	Mar-91	124	0	0	0	0	2.3E+07	6.5E-05	0.1705	0.1702	1.368	14780
511023	10.1	May-92	138	0	0	0	0	2.6E+07	7.2E-05	0.1886	0.1883	1.428	16470
511023	10.1	Oct-92	143	21	0	0	21	2.9E+07	8E-05	0.2099	0.2096	1.45	18330
511023	10.1	Dec-93	157	0	0	0		3.2E+07	8.8E-05	0.2308	0.2305	1.945	20170
511023	10.1	Sep-95	178	105	0	0	105	3.8E+07	0.0001	0.274	0.2736	2.092	24090
511023	10.1	Feb-96	183	167	0	0	167	3.8E+07	0.0001	0.2742	0.2739	2.2	24130
511023	10.1	Mar-97	196	4	0	0	4	4.1E+07	0.00011	0.2921	0.2918	2.269	25830
512021	7.5	Oct-89	54					8.5E+07	0.00013	0.4441	0.43795	56.96	61660
512021	7.5	Mar-91	71					1.1E+08	0.00017	0.5618	0.55422	69.27	79350
512021	7.5	Oct-92	90	21	0	0	21	1.5E+08	0.00023	0.7794	0.76934	106.4	109500
531008	3.4	Jul-91	153	6	0	0	6	2E+08	0.00048	1.285	1.2593	1750	160600
531008	3.4	Jun-93	176	66	0	0	67	2.3E+08	0.00054	1.452	1.42431	1769	184000
531008	3.4	Jun-94	188	8	5	8	21	2.5E+08	0.00058	1.57	1.53893	2370	199800
561007	2.8	Jul-90	121					9.9E+07	0.00035	0.8719	0.77803	575	97420
561007	2.8	May-91	131	0	0	0	0	1.1E+08	0.00036	0.9246	0.81966	671.5	105600
561007	2.8	Aug-91	134	0	0	0	0	1.1E+08	0.0004	0.9931	0.88645	671.6	109800
561007	2.8	Aug-93	158	13	0	0	13	1.3E+08	0.00046	1.162	1.04778	709.7	127300
561007	2.8	Oct-93	160	26	0	0	26	1.3E+08	0.00047	1.17	1.05472	721.7	128600
561007	2.8	Dec-93	162	4	0	0	4	1.3E+08	0.00047	1.177	1.05646	745.5	130700
561007	2.8	Mar-94	165	6	0	0	6	1.4E+08	0.00047	1.188	1.06166	782.3	133900
561007	2.8	Apr-94	166	0	0	0		1.4E+08	0.00047	1.191	1.06426	782.4	134500
561007	2.8	Aug-94	170	6	0	0	6	1.4E+08	0.00049	1.237	1.10763	782.4	138100

Table E-2 (Cont'd) Measured Longitudinal Fatigue Cracking and Predicted Top-Down Damage Using MS-1 Model.

Section	Total AC Thick	Date	Time	Measured Longitudinal Cracking (ft)				Predicted Top-Down Damage (%) (At Different β_{f2} and β_{f3})					
				Low	Med	High	Total	1.0,2.5	1.2,0.8	1.2,1.5 (Ave Thermal)	1.2,1.5 (No Thermal)	1.2,1.5 (max Thermal)	1.2,2.5
561007	2.8	Feb-95	176	7	0	0	7	1.5E+08	0.0005	1.263	1.12411	896.7	143900
561007	2.8	May-95	179	0	0	0		1.5E+08	0.0005	1.274	1.13365	896.7	145300
561007	2.8	Sep-95	183	0	0	0		1.5E+08	0.00052	1.324	1.18049	896.8	149100
561007	2.8	Jun-96	192	5	0	0	5	1.6E+08	0.00053	1.363	1.21258	925.7	155400
561007	2.8	Oct-96	196	0	0	0		1.6E+08	0.00056	1.426	1.27503	925.8	159600
561007	2.8	Nov-96	197	2	0	0	2	1.6E+08	0.00056	1.427	1.2759	926.3	159900
561007	2.8	Mar-97	201	0	0	0		1.6E+08	0.00056	1.434	1.28111	934.6	161800
561007	2.8	Aug-97	206	3	0	0	3	1.7E+08	0.0006	1.517	1.36437	934.7	167300
561007	2.8	Sep-97	207	0	0	0		1.7E+08	0.00061	1.527	1.37391	934.7	168100

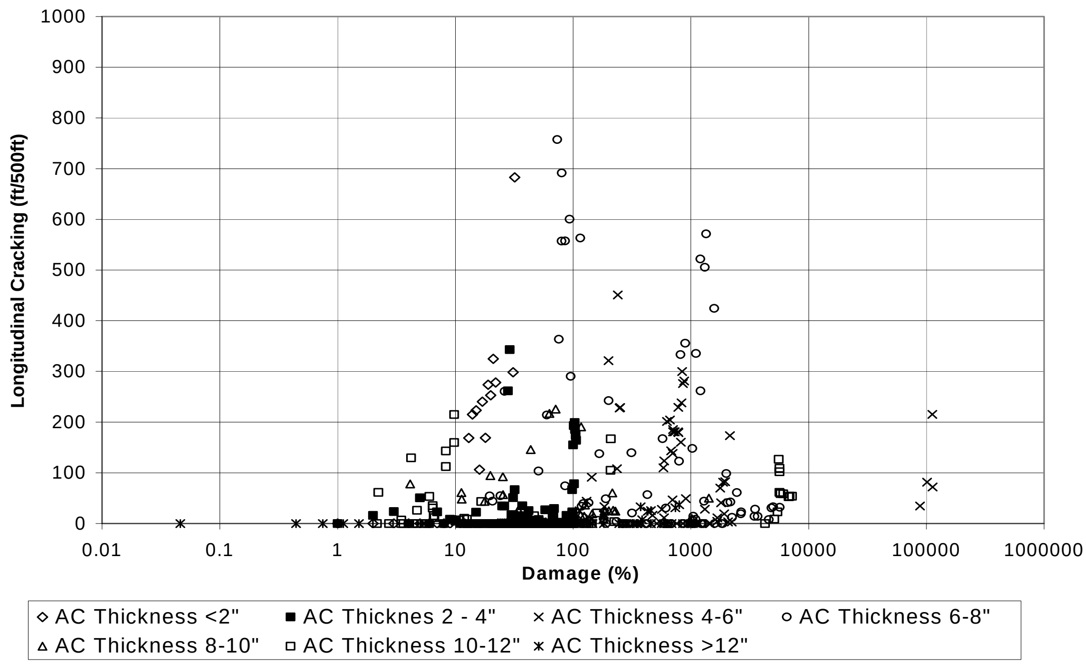

Figure E-1 Longitudinal Cracking vs. Predicted Top-Down Damage (AC 1,0.8,0.8)

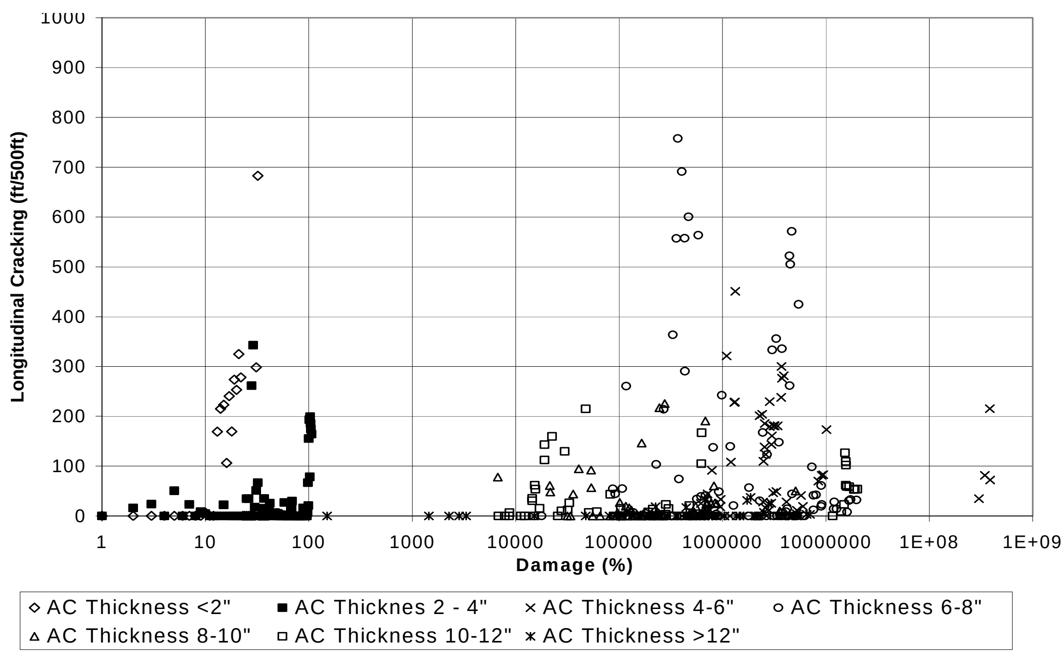

Figure E-2 Longitudinal Cracking vs. Predicted Top-Down Damage (AC 1, 0.8,1.5)

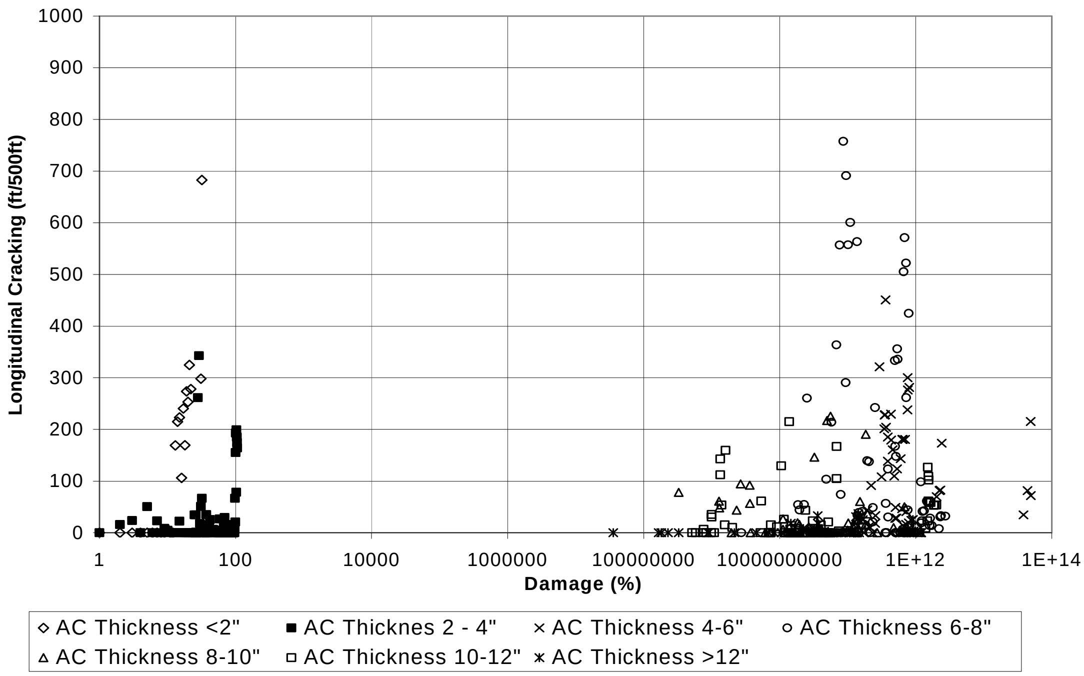

Figure E-3 Longitudinal Cracking vs. Predicted Top-Down Damage (AC 1, 0.8,2.5)

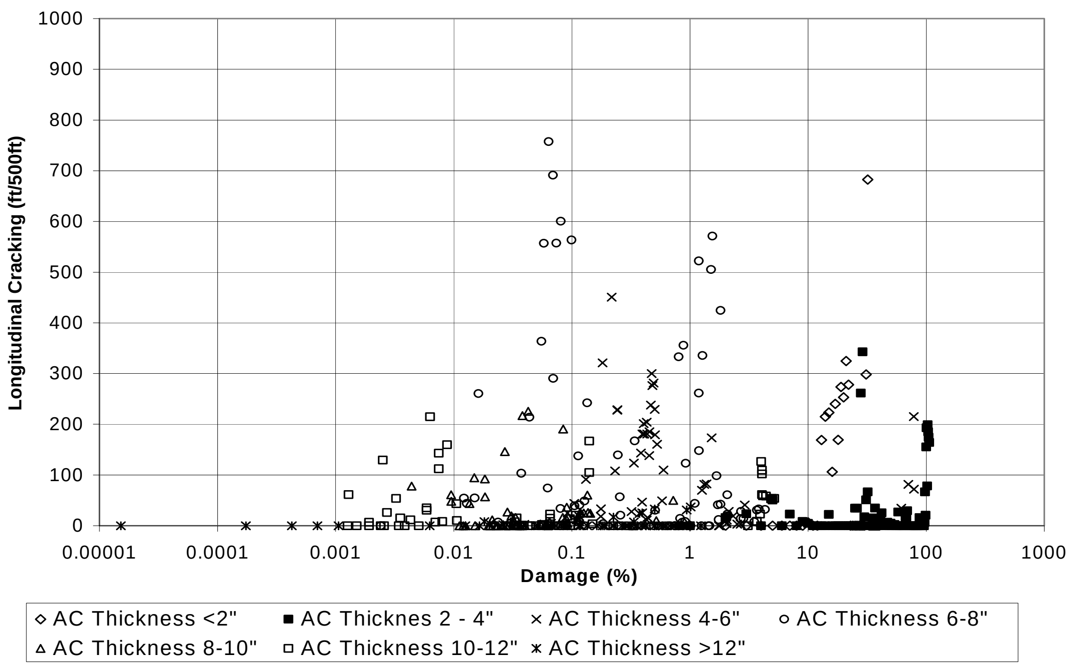

Figure E-4 Longitudinal Cracking vs. Predicted Top-Down Damage (AC 1,1.0, 0.8)

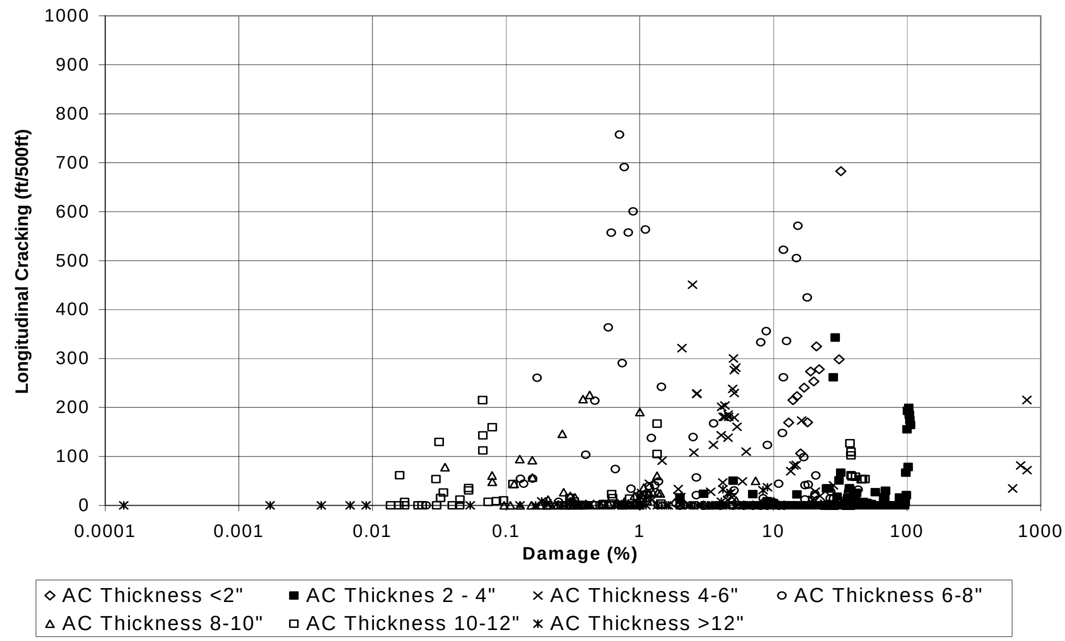

Figure E-5 Longitudinal Cracking vs. Predicted Top-Down Damage (AC 1,1.0,1.0)

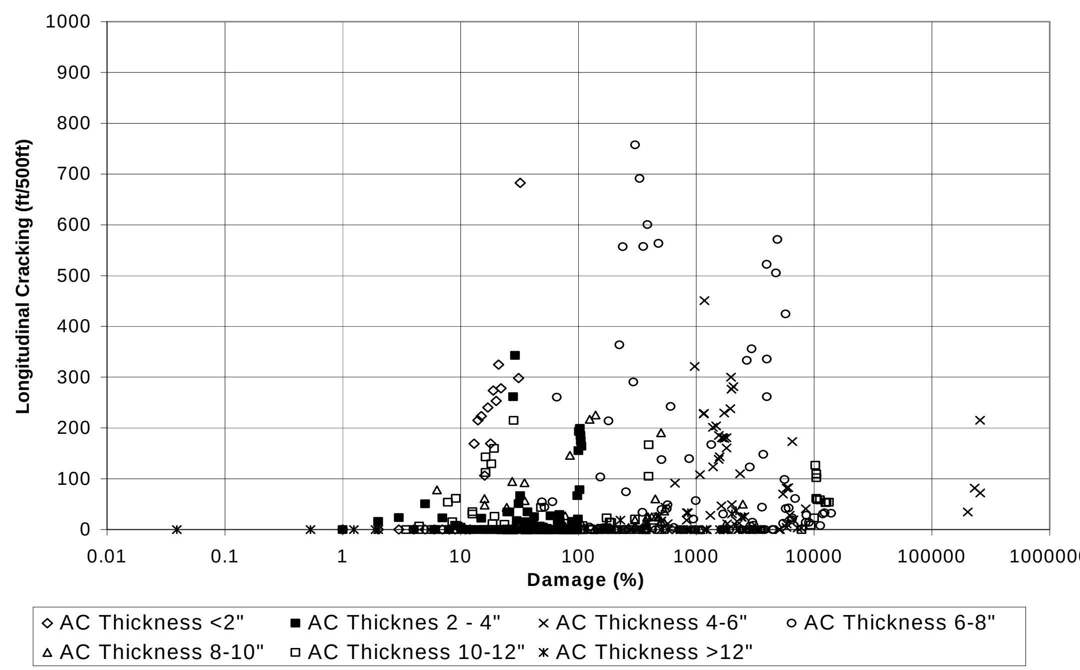

Figure E-6 Longitudinal Cracking vs. Predicted Top-Down Damage (AC 1,1.0,1.5)

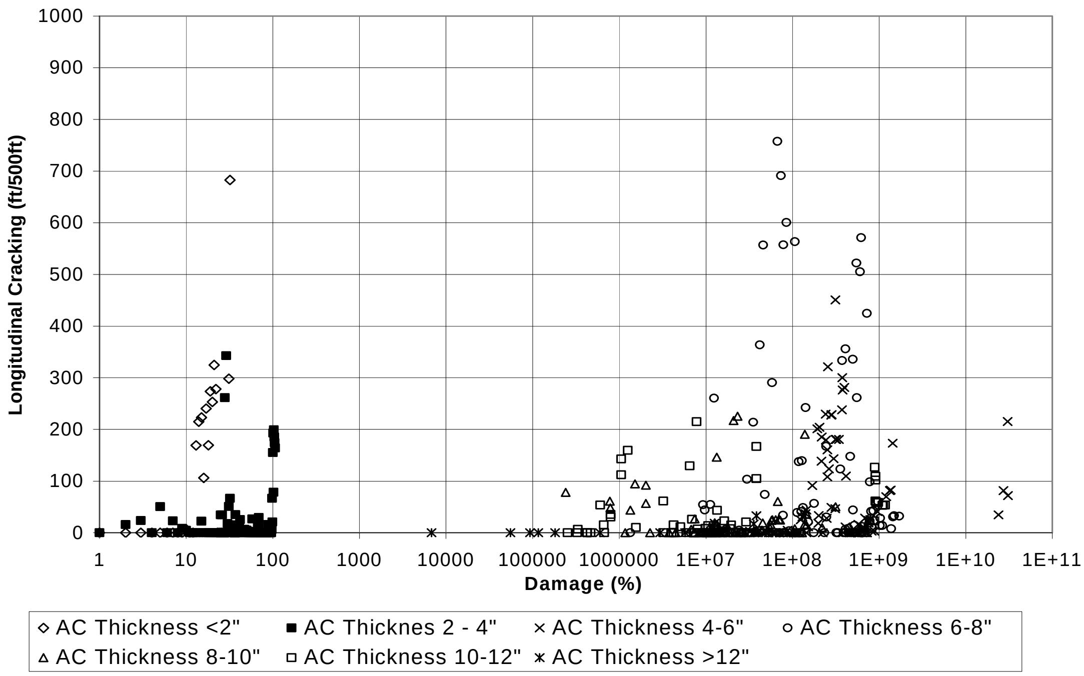

Figure E-7 Longitudinal Cracking vs. Predicted Top-Down Damage (AC 1,1.0,2.5)

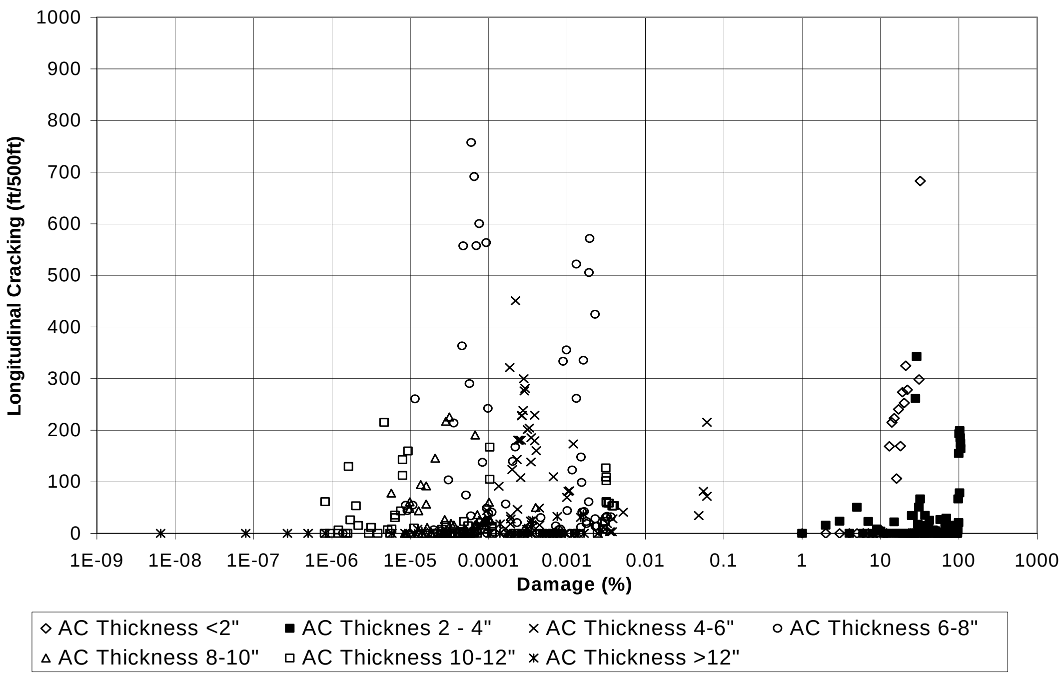

Figure E-8 Longitudinal Cracking vs. Predicted Top-Down Damage (AC 1,1.2, 0.8)

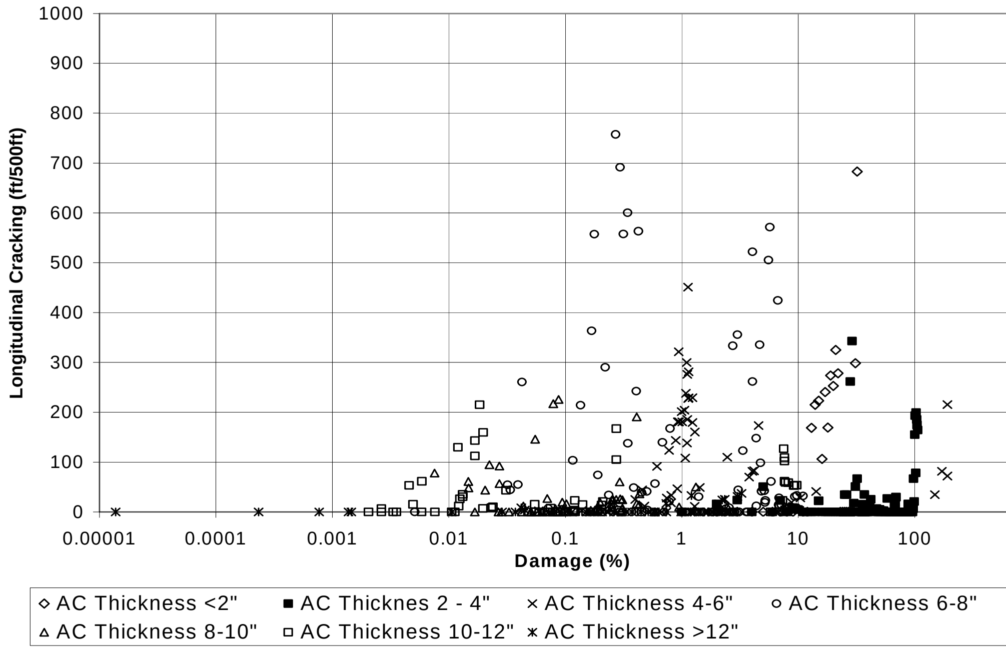

Figure E-9 Longitudinal Cracking vs. Predicted Top-Down Damage (AC 1,1.2,1.5)

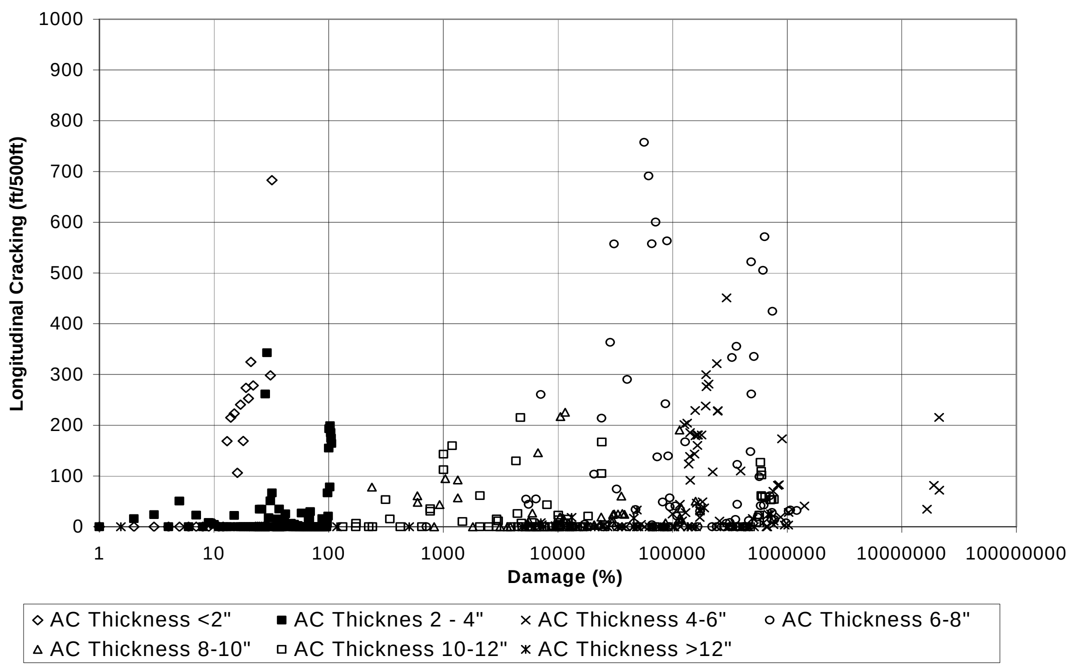

Figure E-10 Longitudinal Cracking vs. Predicted Top-Down Damage (AC 1,1.2,2.5)

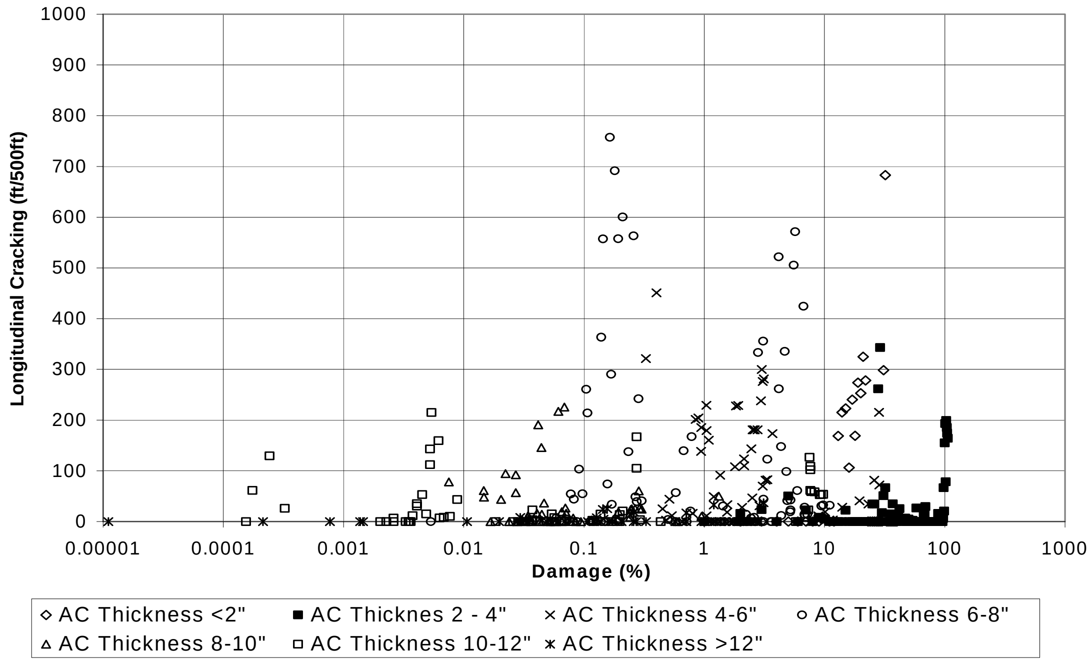

Figure E-12 Longitudinal Cracking vs. Predicted Top-Down Damage (AC 1,1.2,1.5) (No Thermal Strain added)

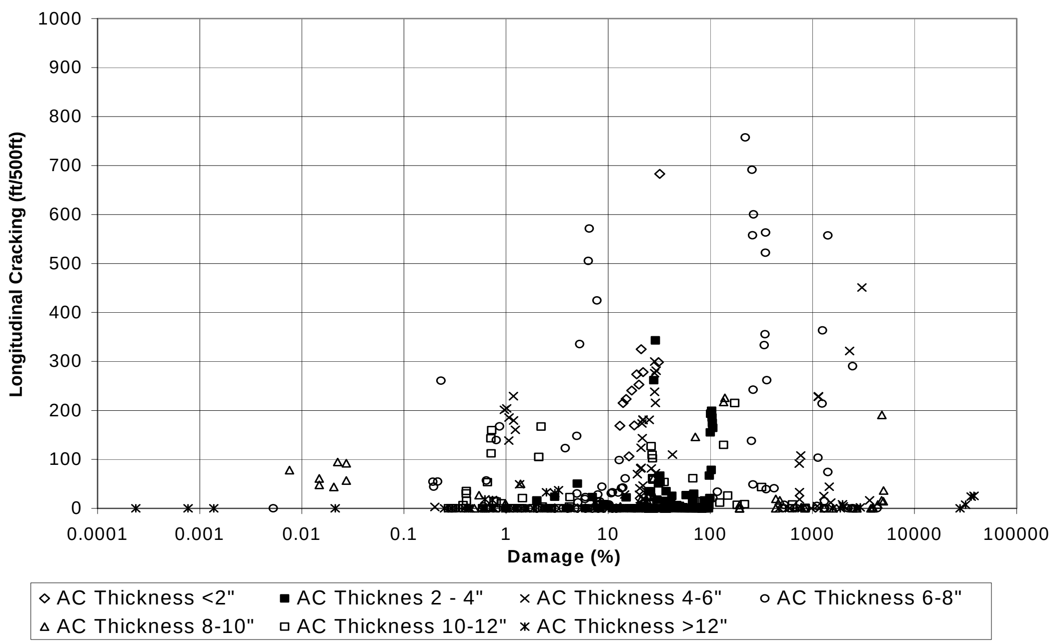

Figure E-13 Longitudinal Cracking vs. Predicted Top-Down Damage (AC 1,1.2,1.5) (Max Thermal Strain added)

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Guide for Mechanistic-Empirical Design
OF NEW AND REHABILITATED PAVEMENT STRUCTURES

FINAL DOCUMENT

APPENDIX II-2:
SENSITIVITY ANALYSIS FOR ASPHALT CONCRETE FATIGUE ALLIGATOR CRACKING

NCHRP

Prepared for
National Cooperative Highway Research Program
Transportation Research Board
National Research Council

Submitted by
ARA, Inc., ERES Division
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Disclaimer

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Research into the subject area covered in this Appendix was conducted at ASU. The authors of this Appendix are Dr. M.W. Witczak, Mr. M. M. El-Basyouny, and Mr. S. El-Badawy.

Foreword

This appendix is the second in a series of three volumes on Calibration of Fatigue Cracking Models for Flexible Pavements. This volume concentrates on the sensitivity analysis for asphalt concrete fatigue alligator cracking.

The other volumes are:

Appendix II-1:	Calibration of Fatigue Cracking Models for Flexible Pavements
Appendix II-3:	Sensitivity Analysis for Asphalt Concrete Fatigue Longitudinal Surface Cracking

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Appendix II-2

Sensitivity Analysis for AC Fatigue Alligator Cracking

APPENDIX II-2: SENSITIVITY ANALYSIS FOR AC FATIGUE ALLIGATOR CRACKING

1 Introduction and Objectives

The objective of this major component of the overall Design Procedure sensitivity study is to investigate how the prediction of fatigue cracking is influenced by changes in magnitude of several different key input variables. To study the sensitivity of these input parameters on fatigue cracking the Design Guide computer program was run using several factorial combinations of the input parameters shown in Table E1-2.1 of this appendix. Unless noted in the specific sensitivity write-up; most of the computer runs used parameters that were typically related to the "Medium" input levels shown in the table.

In general, the sensitivity study of fatigue cracking was not intended to cover a complete full factorial matrix of all parameters. Rather, the intent was to investigate the effect of varying one parameter at a time, while keeping as many of the other variables to be constant input parameters.

The independent parameter that is used for the Design Guide prediction for the fatigue distress is the amount of cracking. For the classic bottom-ups alligator fatigue cracking distress, the specific value used as the program output for the distress is described as follows:

- Alligator cracking (bottom up) is computed in the program as the area of cracking (in ft^2 / 500 ft / lane). Thus, the maximum area of alligator cracking that can be predicted would be 12ft x 500 ft = 6000 ft^2. Alligator cracking is expressed as a percent value, between 0% and 100%, relative to the predicted area of cracking. As an example, if the program would predict an alligator cracking value of 1000 ft^2 / 500 ft / lane; then the percent alligator cracking would be 1000 ft^2 / 6000 ft^2 = 16.7%.

In order to investigate the overall sensitivity of key parameters to alligator fatigue cracking; a series of individual studies were performed. Each separate study had it's own unique parametric objective. The sensitivity analysis for fatigue cracking covered the following items shown below. The paragraph where the sensitivity study outcome is reported and discussed is also shown in the following list:

Paragraph - Study ID

3.1 Influence of AC Mix Stiffness upon Fatigue (Alligator) Cracking (Thin AC Layers)

3.2 Influence of AC Mix Stiffness upon Fatigue (Alligator) Cracking (Thick AC Layers)

3.3 Influence of AC Thickness upon Fatigue (Alligator) Cracking

3.4 Influence of Subgrade Modulus upon Fatigue (Alligator) Cracking

3.5 Influence of AC Mix Air Voids upon Fatigue (Alligator) Cracking

3.6 Influence of Asphalt Content (Effective Bitumen Volume) upon Fatigue (Alligator) Cracking

3.7 Influence of Depth to GWT on Fatigue (Alligator) Cracking

3.8 Influence of Truck Traffic Volume upon Fatigue (Alligator) Cracking

3.9 Influence of Traffic Speed upon Fatigue (Alligator) Cracking

3.10 Influence of Traffic Analysis Level upon Fatigue (Alligator) Cracking

3.11 Influence of MAAT upon Fatigue (Alligator) Cracking

3.12 Influence of Bedrock Depth upon Fatigue (Alligator) Cracking

Prior to presenting the sensitivity report results; the following section of this report describes the general input parameters (and ranges of variables) that have been utilized in the study.

2 Major Program Input Parameters Used in Study

2.1 Introduction

To study the effect of the desired sensitivity input parameter on alligator fatigue cracking, the major pavement design input parameters were usually selected from one of three different levels of the parameter under study (Low, Medium and High). In certain special cases, a fourth level was employed to insure that an adequate range of the variable examined could be evaluated for the sensitivity study. In general, the majority of program runs were conducted using the "Medium levels" of all of the input variables, while varying the major parameter whose sensitivity was being examined. However, in some cases, traffic levels using a "High approach" were used to insure that adequate quantitative cracking levels would be obtained in the sensitivity runs. Table 2.1 shows the different input parameters used in this study and the three to four different levels for each parameter that were eventually investigated. Specifics concerning all of these input values are explained in the following sections.

2.2 Design Parameters and Pavement Structure

For the alligator fatigue cracking sensitivity analysis, only the deterministic analysis was used in the study. The design life selected for each program run was 10 years. This was simply selected to minimize the computational running time required for the entire sensitivity effort. The granular base construction completion date was set two months earlier than the asphalt construction completion date for all problems, while the traffic opening date was set to be the same as the asphalt construction completion date.

A simple conventional flexible pavement cross-section was used in the study. The structure is a three-layer pavement system with a single asphalt concrete layer, an unbound granular base layer (10 inches thick) and a subgrade. Figure 2.1 shows the pavement structure used in the study. The asphalt layer thickness was varied from 1 - 12 inches to study the effect of AC thickness on alligator fatigue cracking. However, the thickness of the unbound granular base was fixed at 10 inch, for all problems analyzed.

2.3 Traffic

Two traffic methods were eventually used in the study: a general traffic module using the load spectrum (Level 1 type of analysis) and a classical 18 kip ESAL approach. The traffic volume was expressed by the average annual daily truck traffic (AADTT) selected to represent a very high traffic volume (50,000 daily truck), high truck traffic (7000 daily trucks), medium high traffic (4000 daily trucks), medium traffic (1000 daily trucks) and a low traffic (100 daily trucks). The general 10-year E18KSAL repetitions for these traffic levels are approximately: 100 million, 15 million, 8 million, 2 million and 200,000. The rest of the traffic parameters were set to the default values given by the software.

Tables 2.2 to 2.5 show the values of the various traffic parameter inputs used in this study. Information regarding the general traffic parameters (Table 2.2), AADTT distributions by vehicle class (Table 2.3), number of axles per truck (Table 2.4) and the axle configurations (Table 2.5) is illustrated. The monthly adjustment factors for traffic were set at 1; while the standard deviation of traffic wander was taken to be 10 inches. Finally, no traffic growth was considered in the study.

2.4 Climate

Three different climatic regions were selected in the sensitivity study of fatigue cracking. The climatic stations were selected to cover a broad range of US temperature conditions (cold, intermediate and hot region). One city was selected from each region to represent the climatic region. The cities were Minneapolis (Minnesota) for the cold climate, Oklahoma City (Oklahoma) for the intermediate climate and Phoenix (Arizona) for the hot weather. The mean annual air temperatures (MAAT) for these three stations were 46.1, 60.7 and 74.4 ºF, respectively.

Table 2.1 Parameters Used in the Sensitivity Runs

	Very Low	Low (L)	**Medium (M)**	Medium High	High (H)	Very High
Traffic Volume – AADTT (Vehicle/Day)		100	**1000**	4000	7000	50,000
(10 years) 18 Kips ESALs		$2*10^5$	$\mathbf{2*10^6}$	$8*10^6$	$1.5*10^7$	$1.0*10^8$
Facility Type (Operating Speed (mph))	Intersection (2.0)	Urban Streets (25)	**State Primary (45)**		Interstate (60)	
Location (MAAT)		Minnesota (46.1ºF)	**Oklahoma (60.7ºF)**		Phoenix (74.4ºF)	
GWT depth (ft)		2	**7**		15	
AC Thickness (in)		1	**4**		12	
AC Stiffness (See Table 2.6)		Low Mix	**Med Mix**		High Mix	
AC Air Voids (@ time of Construction For Med Mix)		4	**7**		10	
AC Effective Binder Content		8	**11**		15	
SG Modulus (psi) (Plasticity index)	3,000 (45)	8,000 (30)	**15,000 (15)**		30,000 (0)	

AC

GB 10” A-1-b (38,000 psi)

SG

Figure 2.1 Pavement Structure

Table 2.2 Traffic Parameters used in the Study

Number of lanes in design direction	2
Percent of trucks in design direction (%)	50
Percent of trucks in design lane (%)	95
Design lane (ft)	12
Standard deviation of Traffic Wander (inch)	10

Table 2.3 AADTT Distributions by Vehicle Class

Class 4	1.8%
Class 5	24.6%
Class 6	7.6%
Class 7	0.5%
Class 8	5.0%
Class 9	31.3%
Class 10	9.8%
Class 11	0.8%
Class 12	3.3%
Class 13	15.3%

Table 2.4 Number of Axles per Truck

Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0.00	0.00
Class 5	2.00	0.00	0.00	0.00
Class 6	1.02	0.99	0.00	0.00
Class 7	1.00	0.26	0.83	0.00
Class 8	2.38	0.67	0.00	0.00
Class 9	1.13	1.93	0.00	0.00
Class 10	1.19	1.09	0.89	0.00
Class 11	4.29	0.26	0.06	0.00
Class 12	3.52	1.14	0.06	0.00
Class 13	2.15	2.13	0.35	0.00

Table 2.5 Axle Configurations

Average axle width (edge-to-edge) outside dimensions, ft)	8.5
Dual tire spacing (in)	12
Single Tire (psi)	120
Dual Tire (psi)	120
Axle Spacing - Tandem axle (in)	51.6
Axle Spacing - Tridem axle (in)	49.2
Axle Spacing - Quad axle (in)	49.2

2.5 Depth to Ground Water Table / Bedrock

For the majority of problems conducted, the ground water table depth (GWT) was set at the Medium level (7 ft), shown in Table 2.1. For the special case, where the effect of the GWT was analyzed for the sensitivity study parameter, it was varied as shown in Table 2.1 to have values of: 2 ft, 7 ft and 15 ft. The presence of a bedrock (stiff) layer was not considered as a variable in any of the studies, except for 3.15 and 3.16, which evaluated the influence of bedrock layers (1 to 20 ft) upon fatigue cracking. The GWT depth and the depth to bedrock are measured from the surface of the pavement.

2.6 Material Characterizations

2.6.1 Asphalt Concrete Mixtures

Three different asphalt concrete mixtures were used in this study. The range of E* master curves (mix stiffnesses) selected was based upon using as broad a range in stiffness of historic AC mixtures as possible. Table 2.6 shows the typical mixture properties as well as typical binder grade and properties. The mixture E* master curves chosen are representative of mixtures utilizing PG 46-34; PG 58-28 and PG 76-16 binders.

Figure 2.2 shows the master curve for the three mixtures. These plots are typically defined, in mathematical models, by use of a sigmoidal function. Table 2.7 shows the dynamic modulus equation parameters (sigmoidal function) for the three AC mixtures utilized in the sensitivity study. The intermediate mixture was selected as the base mixture for the studies in which the air voids and the effective binder content were changed when to study the effect of these two parameters on the AC fatigue cracking.

Table 2.8 summarizes the creep compliance values at different loading time and the tensile strength calculated for the three different asphalt concrete mixtures.

2.6.2 Unbound Layers Material

The unbound granular base properties were the same for all computer runs used in this study. However, the material properties for the subgrade soil were changed to reflect a very broad range of support values, from "very low" (Mr=3000 psi) to "high" (Mr=30,000 psi) conditions. These input values represent the "Design Conditions" for input into the program. Table 2.9 summarizes the input properties of the granular base and the four different subgrade soils used in this study.

Table 2.6 Asphalt Mixture properties

Variable	Low Mix	Med Mix	High Mix
Air Voids (%)	7	7	8
Effective Binder content (%)	12	11	10
VFA (%)	63	61	55
% Retained ¾”	0	11.62	30
% Retained 3/8”	1.16	35.3	47
% Retained # 4	27.65	52.64	52.8
% Passing # 200	11.12	7.28	8.38
PG Grade	46-34	58-28	76-16
Binder A	11.504	11.01	10.015
Binder VTS	-3.901	-3.701	-3.315

Table 2.7 Asphalt Concrete Dynamic Modulus Parameters (Sigmoidal Model Form)

Dynamic Modulus Parameters	Low Mixture	Med Mixture	High Mixture
Delta	2.8657	2.8234	-0.6719
Alpha	3.8185	3.9435	4.1776
Beta	-0.4236	-0.7920	-1.2554
Gamma	0.313351	0.313351	0.313351
C	1.255882	1.255882	1.255882

Table 2.8 Creep Compliance and Tensile Strength for each AC Mixture.

Low Mix

Loading Time (sec)	Creep Compliance (1/psi)		
	Temp (-20 ^oC)	Temp (-10 ^oC)	Temp (0 ^oC)
1	2.928E-07	3.955E-07	5.342E-07
2	3.681E-07	5.670E-07	8.732E-07
5	4.984E-07	9.128E-07	1.672E-06
10	6.267E-07	1.309E-06	2.733E-06
20	7.880E-07	1.876E-06	4.467E-06
50	1.067E-06	3.021E-06	8.554E-06
100	1.341E-06	4.331E-06	1.398E-05
Tensile Strength (psi)		467.4	

Med Mix

Loading Time (sec)	Creep Compliance (1/psi)		
	Temp (-20 ^oC)	Temp (-10 ^oC)	Temp (0 ^oC)
1	2.981E-07	4.027E-07	5.440E-07
2	3.302E-07	4.835E-07	7.081E-07
5	3.779E-07	6.157E-07	1.003E-06
10	4.185E-07	7.393E-07	1.306E-06
20	4.634E-07	8.876E-07	1.700E-06
50	5.303E-07	1.130E-06	2.409E-06
100	5.873E-07	1.357E-06	3.136E-06
Tensile Strength (psi)		413.44	

High Mix

Loading Time (sec)	Creep Compliance (1/psi)		
	Temp (-20 ^oC)	Temp (-10 ^oC)	Temp (0 ^oC)
1	3.284E-07	4.437E-07	5.993E-07
2	3.568E-07	5.023E-07	7.069E-07
5	3.982E-07	5.917E-07	8.794E-07
10	4.326E-07	6.698E-07	1.037E-06
20	4.700E-07	7.583E-07	1.223E-06
50	5.244E-07	8.934E-07	1.522E-06
100	5.697E-07	1.011E-06	1.795E-06
Tensile Strength (psi)		392.5	

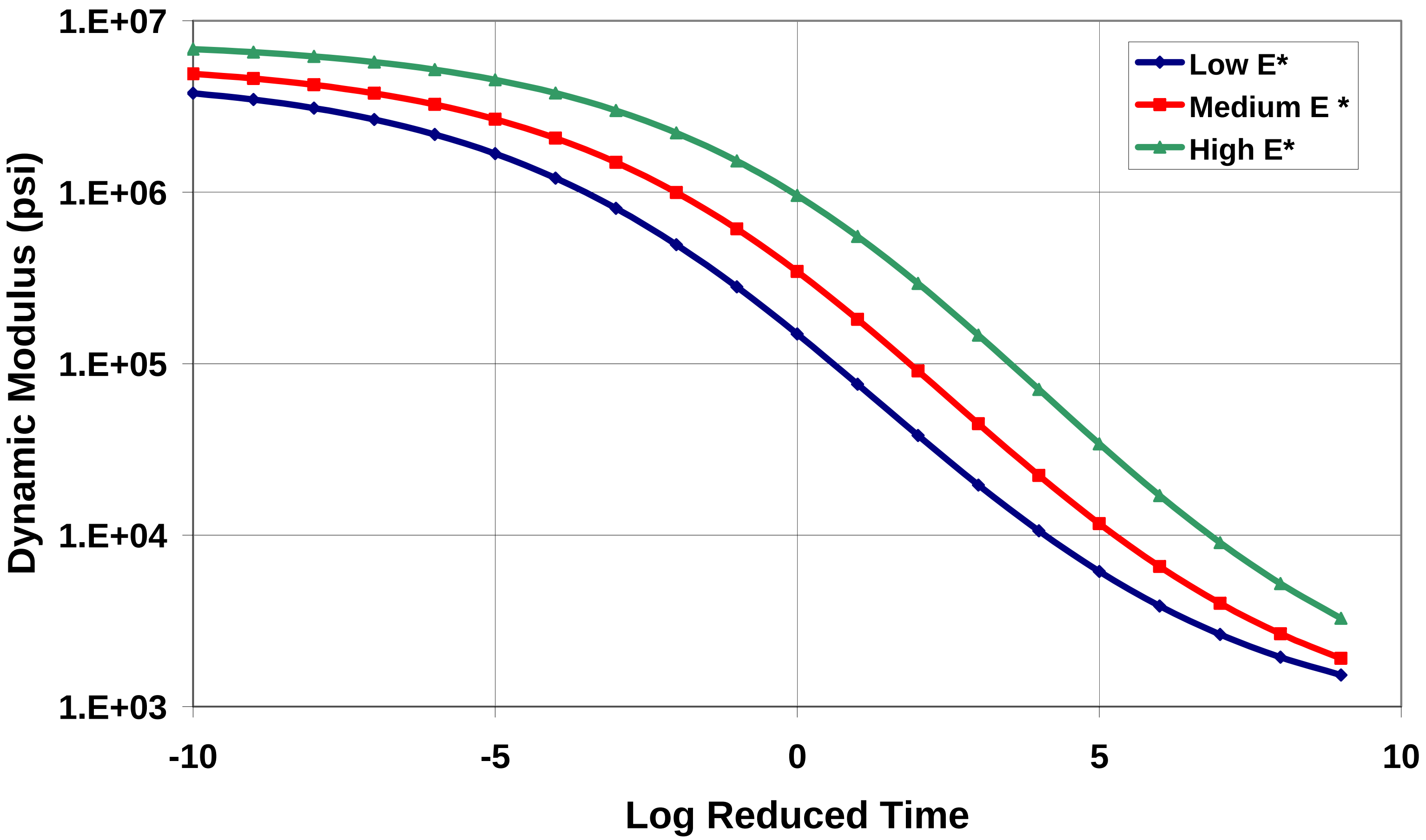

Figure 2.2 Asphalt Concrete Mixtures Master Curves

Table 2.9 Unbound Material Properties

Layer	GB	SG Very low	SG Low	SG Med	High
Classification	A–1–b	CL	A–7–6	A – 6	A – 3
Modulus (psi)	38,000	3,000	8,000	15,000	30,000
Plasticity Index – PI (%)	0	45	30	15	0
% Passing # 4	40	100	100	95	85
% Passing # 200	3	97	80	50	7
D_{60} (mm)	2	0.01	0.02	0.1	0.3

3 Sensitivity Analysis for AC Alligator Fatigue Cracking

The following sections of this report describe the individual sensitivity studies that were conducted for the alligator (bottom-up) fatigue cracking analysis. The ensuing sections are presented by individual reports associated with each of the individual studies noted in section 1 of this report.

3.1 Influence of AC Mix Stiffness upon Fatigue (Alligator) Cracking (Thin AC Layers)

3.1.1 Objective

The objective of this section is to study the effect of changing the AC mix stiffness upon the amount of alligator fatigue cracking in thin AC layers.

3.1.2 Input Parameters

a. Traffic: High traffic volume (7000 AADTT)
b. Traffic Speed: 45 mph
c. Environment: Oklahoma
d. Depth to GWT: Medium (7 ft)
e. Pavement Cross Section: Three layered system as shown in Figure 2.1
f. Layer properties:
    - AC layer: 1 inch
    - AC Mix Stiffness: Low, Medium and High as shown in Table 2.6 and Figure 2.2
    - Granular Base layer: As shown in Table 2.9 and Figure 2.1
    - Subgrade: Four different subgrade support values used (Mr=30,000; 15,000; 8,000 and 3,000 psi) as shown in Table 2.9
g. Depth to bedrock: No Bedrock present

3.1.3 Results

Figures 3.1-1 shows the percentage of alligator cracking after 10 years of loading for three levels of AC layer stiffness and four different levels of subgrade modulus. It is very important to recognize that these results are representative for only a very thin (1 inch thick) layer of asphaltic mix.

3.1.4 Discussion of Results

The results shown in the figure are very important for the reader to comprehend. First of all, as is intuitive, regardless of the AC modulus value (E* stiffness range); alligator cracking decreases with increasing subgrade support (modulus). However, the most important lesson to be drawn from this sensitivity analysis is related to the fundamental fact that, for very thin AC layers, the best AC mixture is one that exhibits a very low stiffness Master Curve. As the mixture becomes more and more stiff, the amount of alligator cracking, due to bottoms up fatigue fracture, greatly increases.

In essence, if very thin AC layers are used, the engineer must insure that a very soft (i.e. high AC% mix, small nominal aggregate size, soft - low viscosity binder) mixture is used. If a very stiff mixture is placed in a thin layer, the probability of obtaining excessive fatigue cracking is very likely. Finally, it is important to understand that the AC mixture stiffness principles, presented for this one-inch thick AC layer, will change as the thickness of the AC layer is changed.

3.1.5 Summary and Conclusions

For very thin AC layers, alligator (fatigue cracking) will greatly be increased as the stiffness of the AC mix becomes larger. The rate of change in alligator cracking is small at low to medium ranges of mixture stiffness, but increases significantly as very high mix stiffnesses are used in the pavement structure.

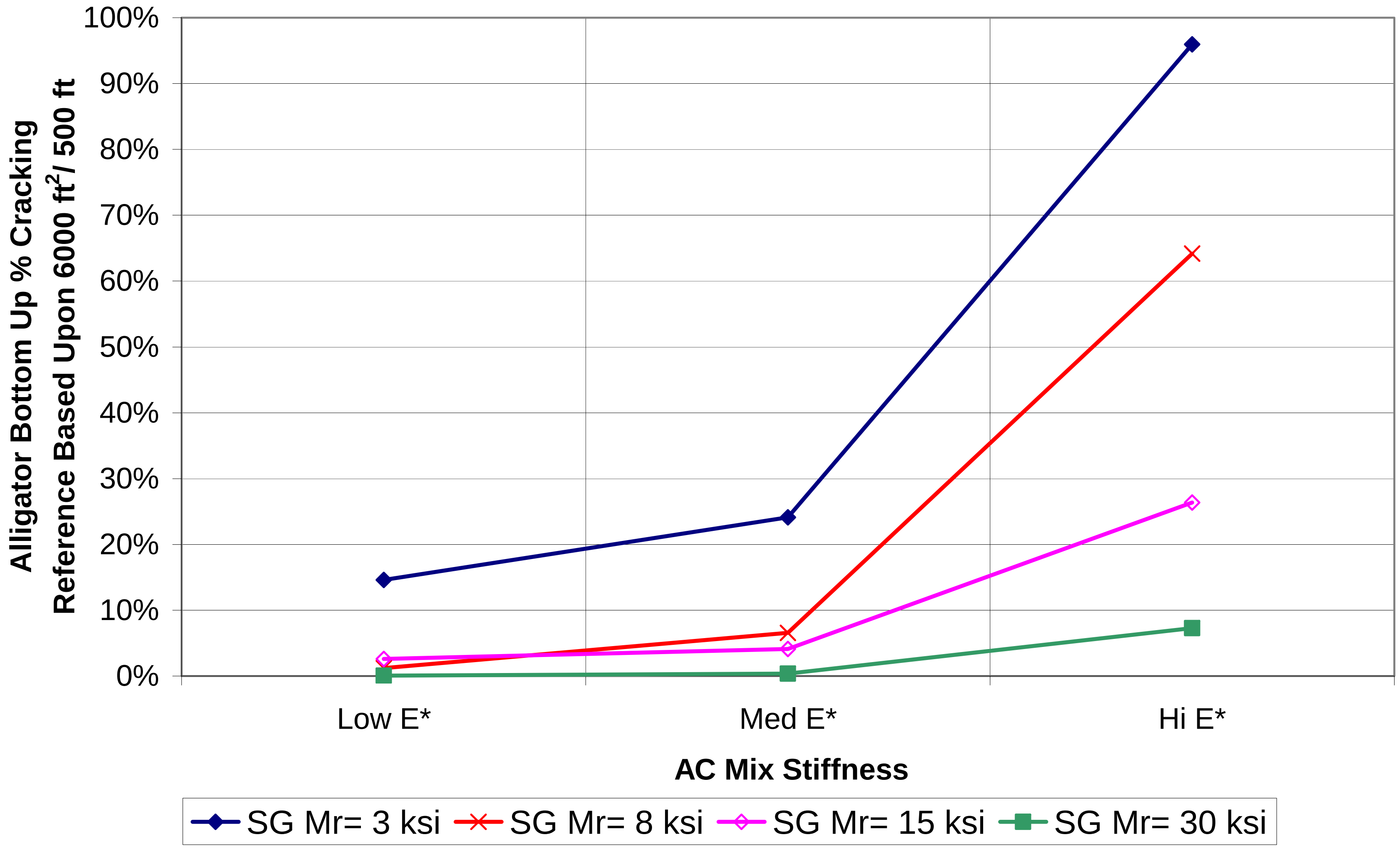

Figure 3.1-1 Effect of AC Mix Stiffness on Alligator Cracking, (H_{ac} = 1 in)

3.2 Influence of AC Mix Stiffness upon Fatigue (Alligator) Cracking (Thick AC Layers)

3.2.1 Objective

The objective of this section is to study the effect of changing the AC mix stiffnesses on the amount of alligator fatigue (bottom up) cracking for thick AC layers.

3.2.2 Input Parameters

a. Traffic: High traffic volume (7000 AADTT)
b. Traffic Speed: 45 mph
c. Environment: Oklahoma
d. Depth to GWT: Medium (7 ft)
e. Pavement Cross Section: Three layered system as shown in Figure 2.1
f. Layer properties:
   - AC layer: 10 inch
   - AC Mix Stiffness: Low, Medium and High as shown in Table 2.6 and Figure 2.2
   - Granular Base layer: As shown in Table 2.9 and Figure 2.1
   - Subgrade: Four different subgrade support values used (Mr=30,000; 15,000; 8,000 and 3,000 psi) as shown in Table 2.9
g. Depth to bedrock: No Bedrock present

3.2.3 Results

Figures 3.2-1 shows the percentage of alligator fatigue cracking after 10 years of loading for three levels of AC layer stiffness.

3.2.4 Discussion of Results

As would be expected, the fatigue cracking decreases with an increase in the subgrade modulus. This is due to the fact that tensile strains, and hence fatigue damage, are reduced as the subgrade modulus is increased. However, a most important trend and conclusion is noted relative to the influence of AC stiffness upon alligator cracking. It is observed that for very thick AC sections, fatigue damage (cracking) is increased for low stiffness AC mixtures. This is 180 degrees opposite to the findings of mix stiffness - fatigue damage for very thin AC layers. The influence of AC mix stiffness is more significant as the foundation support decreases. In general, for very large AC thicknesses, low E* mixtures would tend to show more damage (cracking).

3.2.5 Summary and Conclusions

As the AC mix stiffness of thick AC layers increases the amount of alligator fatigue cracking decreases. The higher the subgrade modulus, the lower the alligator cracking would be.

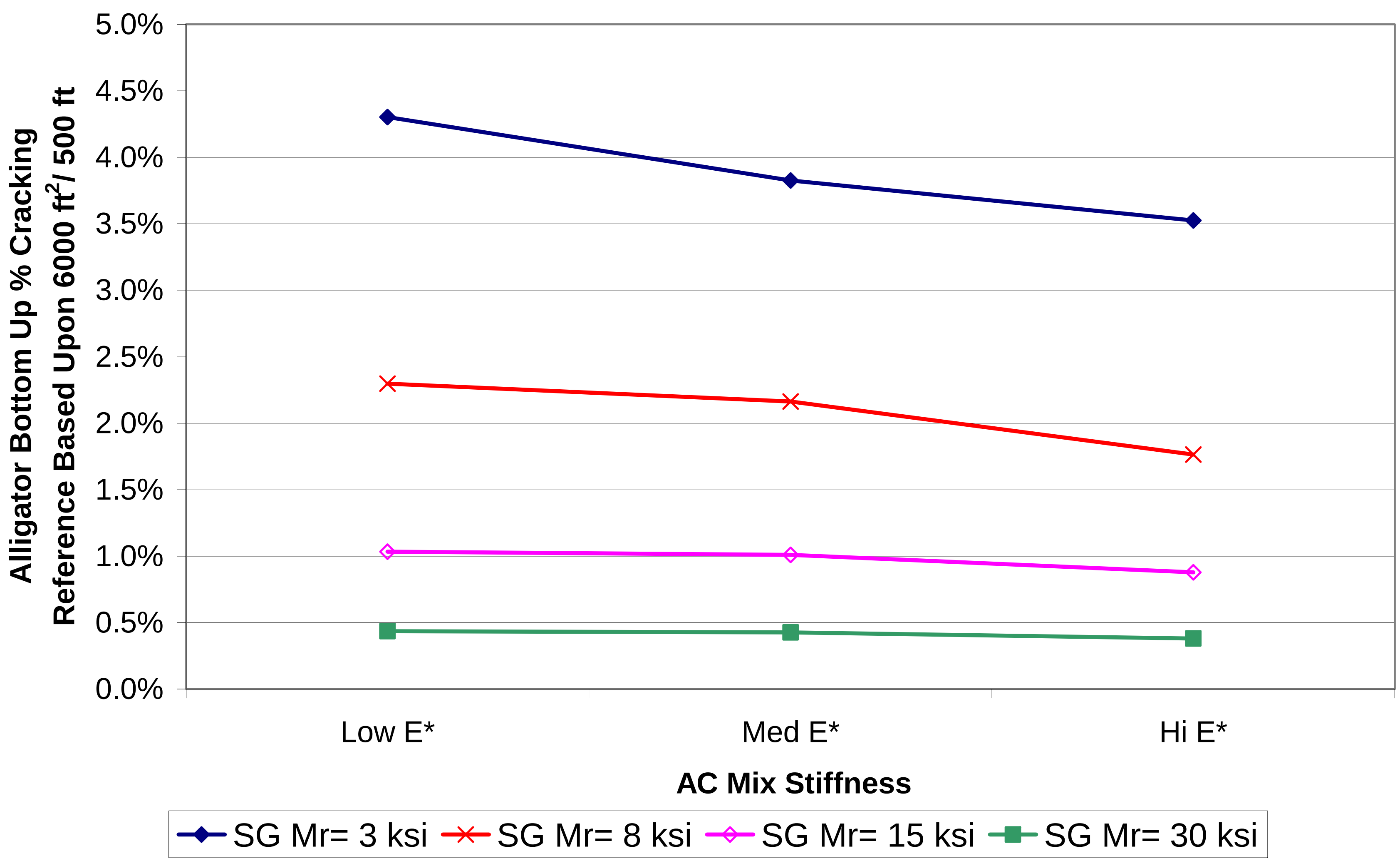

Figure3.2-1 Effect of AC Mix Stiffness on Alligator Cracking, (H_{ac} = 10 in)

3.3 Influence of AC Thickness Upon Fatigue (Alligator) Cracking

3.3.1 Objective

The objective of this section is to study the effect of AC layer thickness on the amount of alligator fatigue cracking.

3.3.2 Input Parameters

a. Traffic: High traffic volume (7000 AADTT)
b. Traffic Speed: 45 mph
c. Environment: Oklahoma
d. Depth to GWT: medium (7 ft)
e. Pavement Cross-Section: Three layered system as shown in Figure 2.1
f. Layer properties:
    - AC layer: 1, 2, 4, 6, 8, 10 and 12 inches
    - AC Mix Stiffness: Medium Stiff Mixture as shown in Table 2.6 and Figure 2.2
    - Granular Base layer: As shown in Table 2.9and Figure 2.1
    - Subgrade: Six different subgrade support values used (Mr=30,000; 25,000; 20,000; 15,000; 8,000 and 3,000 psi) as shown in Table 2.9
g. Depth to bedrock: No Bedrock present

3.3.3 Results

Figure 3.3-1 illustrates the influence of the percentage of alligator fatigue cracking after 10 years of loading, as a function of the AC layer thickness, for various levels of subgrade support.

3.3.4 Discussion of Results

The relationship shown in the figure illustrates another extremely important fundamental fact regarding the distribution of alligator fatigue cracking for flexible pavement systems. First of all, for all levels of AC thickness, it can be clearly observed that the magnitude of alligator cracking is increased as the subgrade support is decreased. It can also be observed that the sensitivity, or impact of the subgrade support upon alligator cracking, is directly related to the thickness of the AC layer.

Perhaps the most important fundamental conclusion that can be drawn from the figure is that for good performance, the proper thickness of AC layers must be either as thin as practical or as thick as possible. It reinforces the adage of old time flexible pavement experts who inferred that " …if you build a pavement thin, it should be thin…if you build it thick, then it should be built thick". The figure clearly indicates that the greatest potential for fatigue fracture is really associated with AC layers that are typically in the 3" to 5" thick range.

The fundamental reasoning behind the results shown in the figure is a powerful example of the utilization of a mechanistic approach to pavement design. It should be intuitive to the reader, that as the AC thickness increases beyond 4 +”, that the tensile strains generated at the bottom of the AC layer are reduced with increasing AC thickness. Thus, it is logical that as the AC thickness is increased beyond a 4" layer, the fatigue life is directly increased due to a smaller tensile strain value occurring in the pavement system. Nonetheless, the real important fact that must be recognized is that the magnitude of the tensile strain does not necessarily increase proportionately to a decrease in AC thickness. In fact, as the AC thickness is reduced below the "maximum cracking level of 3 to 5 inches", the tensile strains actually start to decrease and, in fact, may actually become compressive in nature. Thus, at very thin AC layers, there is little to no tensile stresses or strains that may be found at the bottom of the AC layer. This clearly explains why, fatigue behavior may improve with decreasing levels of AC thickness.

While this is true, the reader must also recognize that, while thin AC layers may not have significant fatigue problems; other major distress types, particularly, repetitive shear deformations, leading to permanent deformation or excessive rutting become the most salient design consideration for these pavement types. One disadvantage of a pavement system that has very small AC layer thicknesses, is the fact that the stress state in the unbound layers (bases, subbases and subgrades) is greatly increased and hence increases the probability of rutting in these unbound layers, overlain by thin layers of AC.

Finally, the implications of these conclusions should not be lost upon the common rehabilitation scenario that is prevalent, in practice, for a great proportion of the AC flexible pavement conditions. It is commonly assumed, by most engineers, that the rehabilitation procedure involving the addition of, say, 2 more inches of AC will improve the performance and life of any pavement structure. From the figure, it is clear that the validity of this statement, is only true for the rehabilitation of existing AC layers that may be 4" or greater. Here the addition of several more inches of an AC overlay clearly will benefit the structural life of the rehabilitated system. On the other, if one starts with an existing 2" AC layer, and then adds a 2" AC overlay, it can be seen that the overlaid (rehabilitated) pavement structure may have a much larger propensity to exhibit fatigue fracture than the original pavement system. These considerations must be taken into account during the rehab design.

3.3.5 Summary and Conclusions

An optimum thickness of the AC layer, near a value of 3 to 5", will exhibit the greatest level of alligator fatigue cracking possible in a pavement system. In addition, cracking will be increased as the subgrade support becomes weaker (poorer). From a fatigue viewpoint, AC layers need to be either very thin or thick. However, it is imperative that all other potential distress modes be also evaluated prior to formulating a final conclusion regarding the design level of the AC layer that needs to be selected.

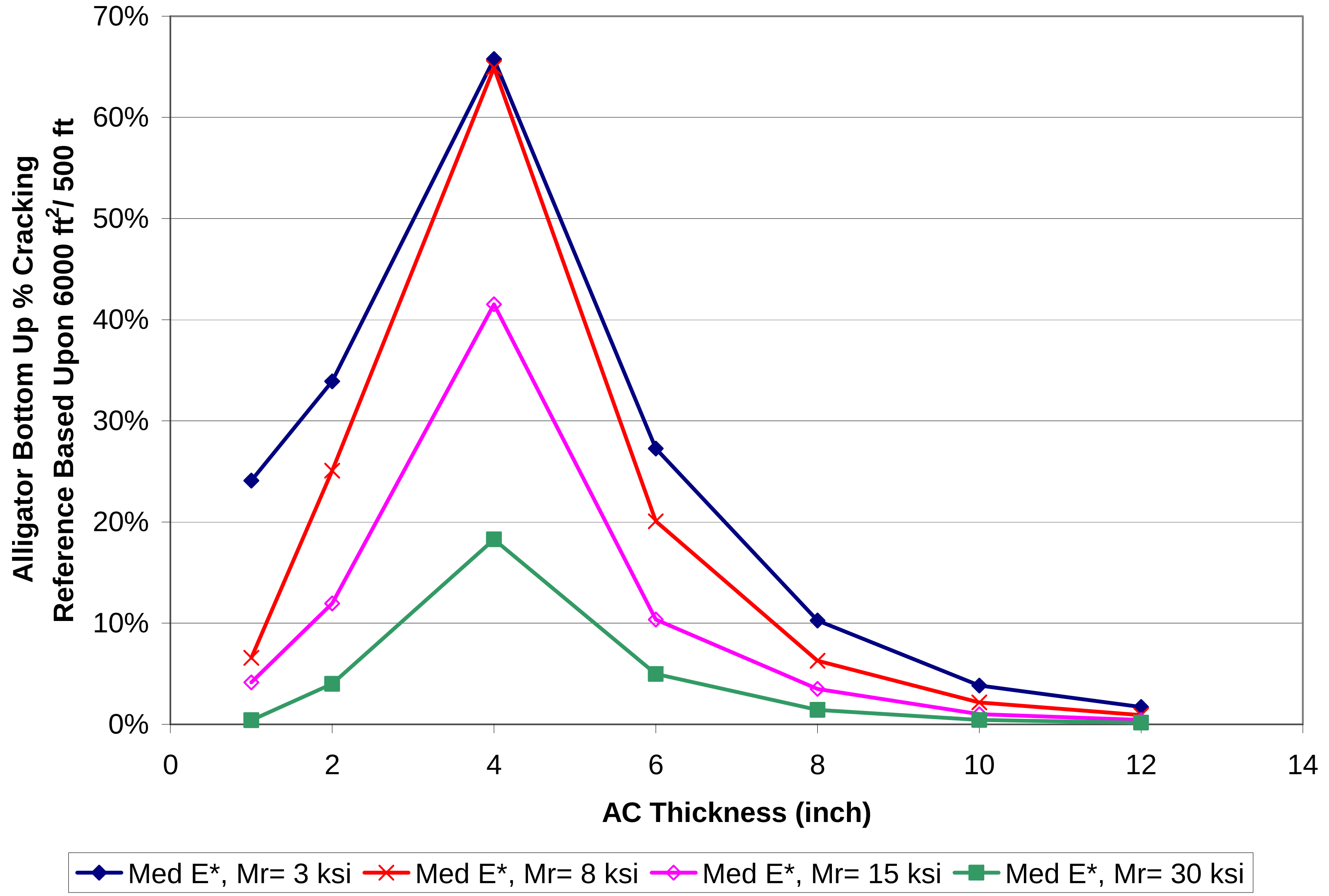

Figure 3.3-1 Effect of AC Layer Thickness on Alligator Fatigue Cracking

3.4 Influence of Subgrade Modulus Upon Fatigue (Alligator) Cracking

3.4.1 Objective

The objective of this section is to study the effect of subgrade modulus on the amount of alligator fatigue cracking.

3.4.2 Input Parameters

a. Traffic: High traffic volume (7000 AADTT)
b. Traffic Speed: 45 mph
c. Environment: Oklahoma
d. Depth to GWT: medium (7 ft)
e. Pavement Cross-Section: Three layered system as shown in Figure 2.1
f. Layer properties:
   - AC layer: 4 inches
   - AC Mix Stiffness: Medium Stiff Mixture as shown in Table 2.6 and Figure 2.2
   - Granular Base layer: As shown in Table 2.9 and Figure 2.1
   - Subgrade: Four different subgrade support values used (Mr=30,000; 15,000; 8,000 and 3,000 psi) as shown in Table 2.9
g. Depth to bedrock: No Bedrock present

3.4.3 Results

Figure 3.4-1 shows the percentage of alligator fatigue cracking after 10 years of loading for the four levels of subgrade modulus used in the sensitivity study.

3.4.4 Discussion of Results

The figure clearly illustrates the fundamental fact that the stronger the foundation (subgrade) support of the pavement system becomes; the less the amount of alligator fatigue cracking that will occur. The relative sensitivity of the rate of alligator cracking, due to variable subgrade support, is a function of many other design variables, such as: traffic, site climatic condition and thickness of the AC layer used in the cross section.

3.4.5 Summary and Conclusions

Increasing the subgrade support modulus will result in a decreased level of alligator fatigue cracking in any pavement system. The sensitivity of subgrade support to the magnitude of alligator cracking is also a function of many other design input parameters as well.

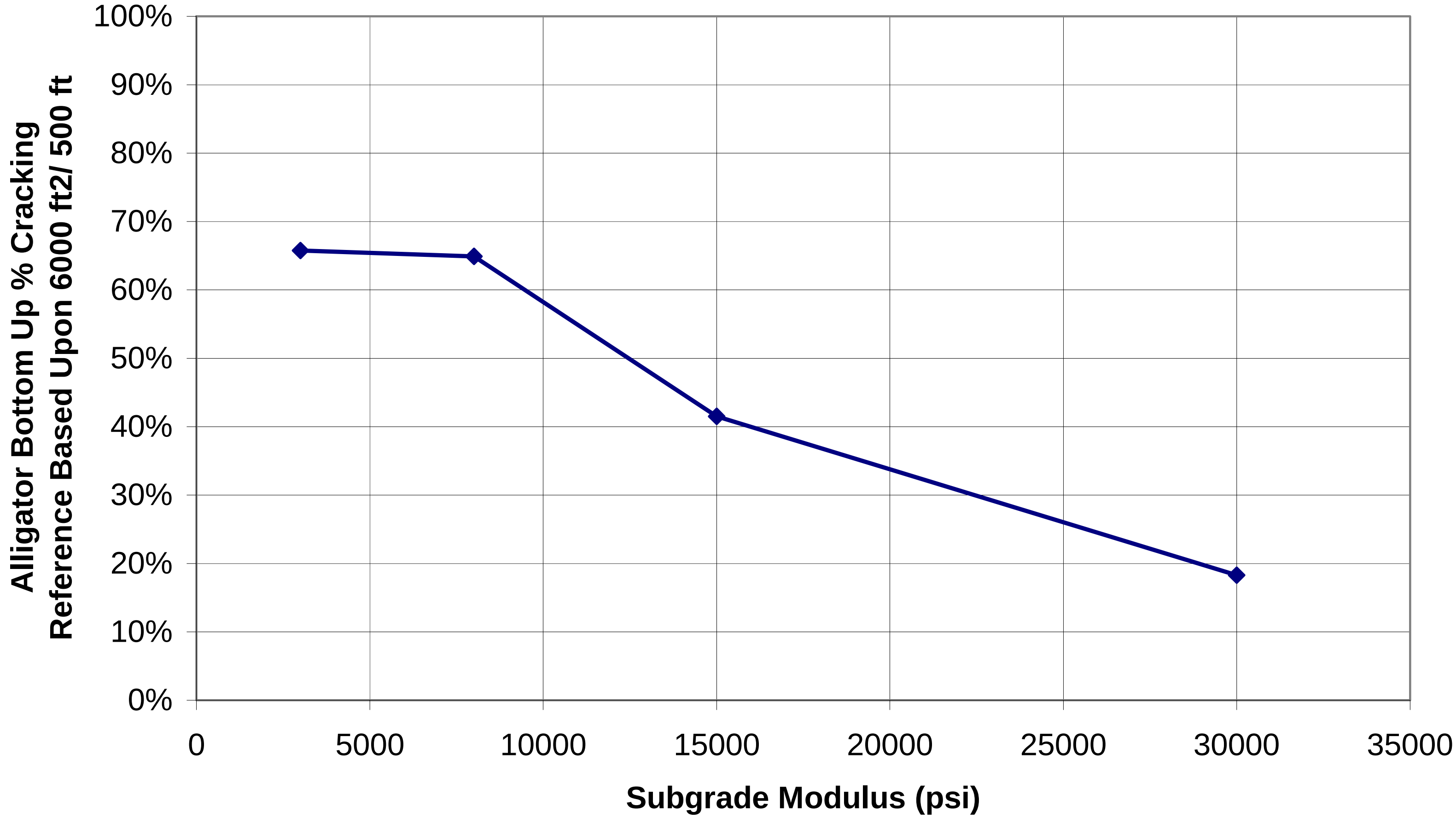

Figure3.4-1 Effect of Subgrade Modulus on Alligator Cracking

3.5 Influence of AC Mix Air Voids Upon Fatigue (Alligator) Cracking

3.5.1 Objective

The objective of this section is to study the effect of the in-situ AC air voids on alligator fatigue cracking.

3.5.2 Input Parameters

a. Traffic: Medium traffic volume (7000 AADTT)
b. Traffic Speed: 45 mph
c. Environment: Oklahoma
d. Depth to GWT: medium (7 ft)
e. Pavement Cross-Section: Three layered system as shown in Figure 2.1
f. Layer properties:
   - AC layer: 4 inches
   - AC Mix Stiffness: Medium Stiff Mixture as shown in Table 2.6 and Figure 2.2
   - AC Mix Air Voids: 4, 7, and 10%
   - Granular Base layer: As shown in Table 2.9 and Figure 2.1
   - Subgrade: Medium Support (Mr=15,000 psi) as shown in Table 2.9
g. Depth to bedrock: No Bedrock present

3.5.3 Results

Figure 3.5-1 shows the percentage of alligator fatigue cracking after 10 years of loading for the three levels of AC mix air voids used in the sensitivity study. The range of air voids used in the study reflects a very real range under typical construction conditions (4% to 10%).

3.5.4 Discussion of Results

The results shown in the figure clearly reflect the critical importance of air voids upon fatigue cracking. The greater the in-place air voids of an asphalt mixture are; the greater the degree of cracking that may be expected. This effect is directly attributable to the volumetric mix term incorporated into both the controlled strain (thin AC layers) and controlled stress (thick AC layers) fatigue equation for bottoms up cracking. In reality, it is the mix Voids Filled with Bitumen parameter that directly influences the fatigue cracking. As this parameter is increased, the cracking is greatly reduced. Thus, this sensitivity study is directly tied to air voids and the AC content. (Also see Study 3.6)

3.5.5 Summary and Conclusions

In summary, the air voids within an AC mixture are an important parameter to influence fatigue cracking. Increasing the amount of air voids in the AC mix may significantly increase the amount of alligator fatigue cracking.

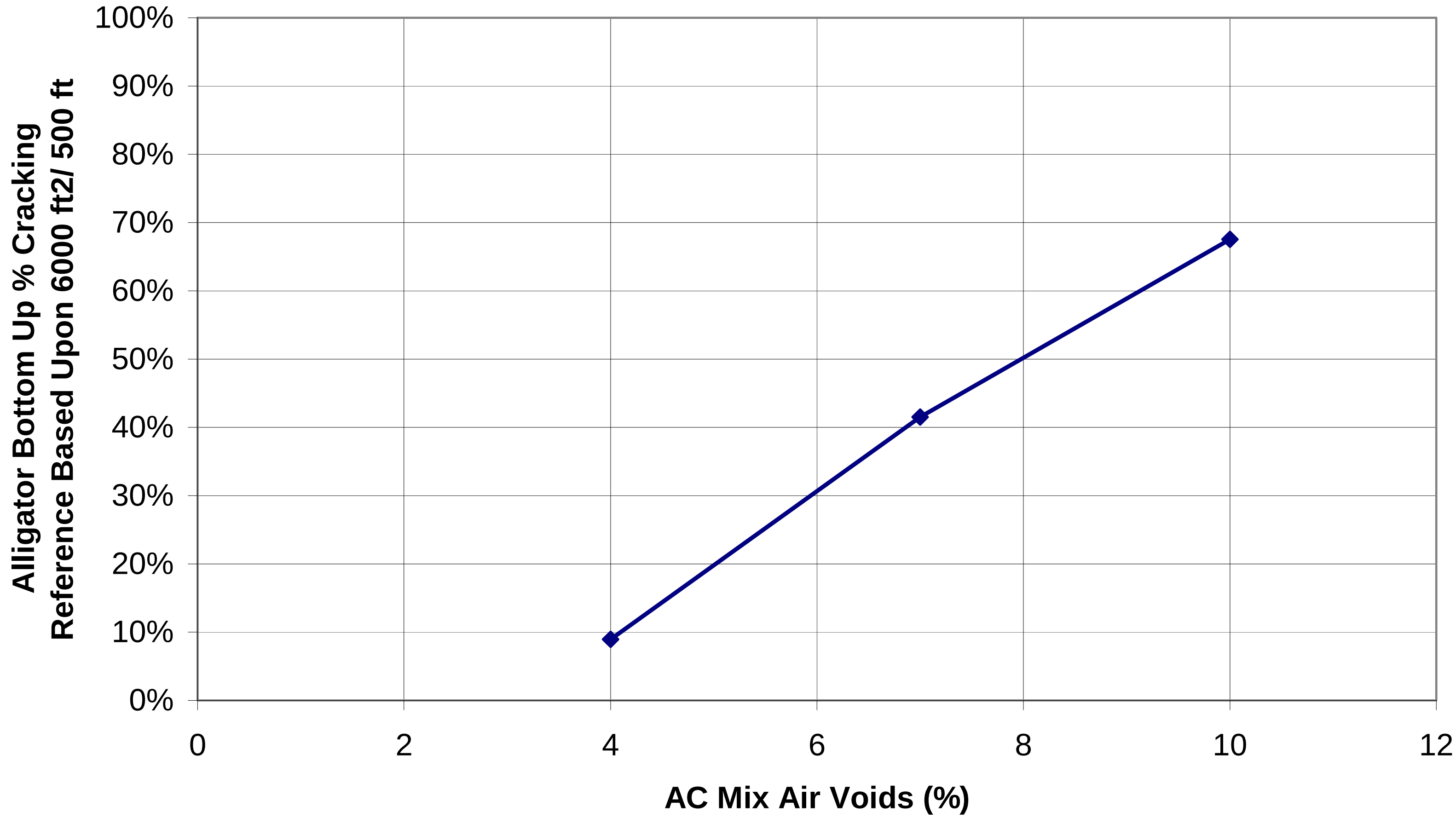

Figure 3.5-1 Effect of Percent AC Mix Air Voids on Alligator Fatigue Cracking

3.6 Influence of Asphalt Content (Effective Bitumen Volume) Upon Fatigue (Alligator) Cracking

3.6.1 Objective

The objective of this section is to study the influence of the magnitude of the effective bitumen volume present in an AC mixture upon the amount of alligator cracking.

3.6.2 Input Parameters

a. Traffic: Medium traffic volume (7000 AADTT)
b. Traffic Speed: 45 mph
c. Environment: Oklahoma
d. Depth to GWT: medium (7 ft)
e. Pavement Cross-Section: Three layered system as shown in Figure 2.1
f. Layer properties:
   - AC layer: 4 inches
   - AC Mix Stiffness: Medium Stiff Mixture as shown in Table 2.6 and Figure 2.2
   - AC Mix Effective Binder Content: 8, 11 and 15%
   - Granular Base layer: As shown in Table 2.9 and Figure 2.1
   - Subgrade: Medium Support (Mr=15,000 psi) as shown in Table 2.9
g. Depth to bedrock: No Bedrock present

3.6.3 Results

Figure 3.6-1 shows the percentage of alligator fatigue cracking after 10 years of loading for three assumed values of effective bitumen volume (Vbe). This parameter is approximately 2.0 to 2.2 times the numerical value of the AC content, in percentage form. Thus the ranges of Vbe = 8, 11 and 15 %, translate into approximate AC % values of 4%, 5+% and 7+%.

3.6.4 Discussion of Results

Like the previous study presented on the influence of mixture air voids, the influence of the amount of asphalt present in a mix also has a significant influence upon the amount of alligator cracking that may occur. It is observed from the figure that there is a decrease in the amount of alligator fatigue cracking as the amount of the effective binder volume increases. This is a direct consequence of the V_{fb} term used in the Fatigue Damage equation. As the asphalt content (effective bitumen content) is increased; the Voids filled with bitumen are also increased. This results in a greater resistance of the mixture to fracture under fatigue damage.

3.6.5 Summary and Conclusions

In summary, the amount of asphalt binder present in a mixture will directly influence the amount of fatigue cracking that will occur in the field. When the effective bitumen volume (amount of asphalt) is increased in a mix; the amount of alligator cracking will be decreased.

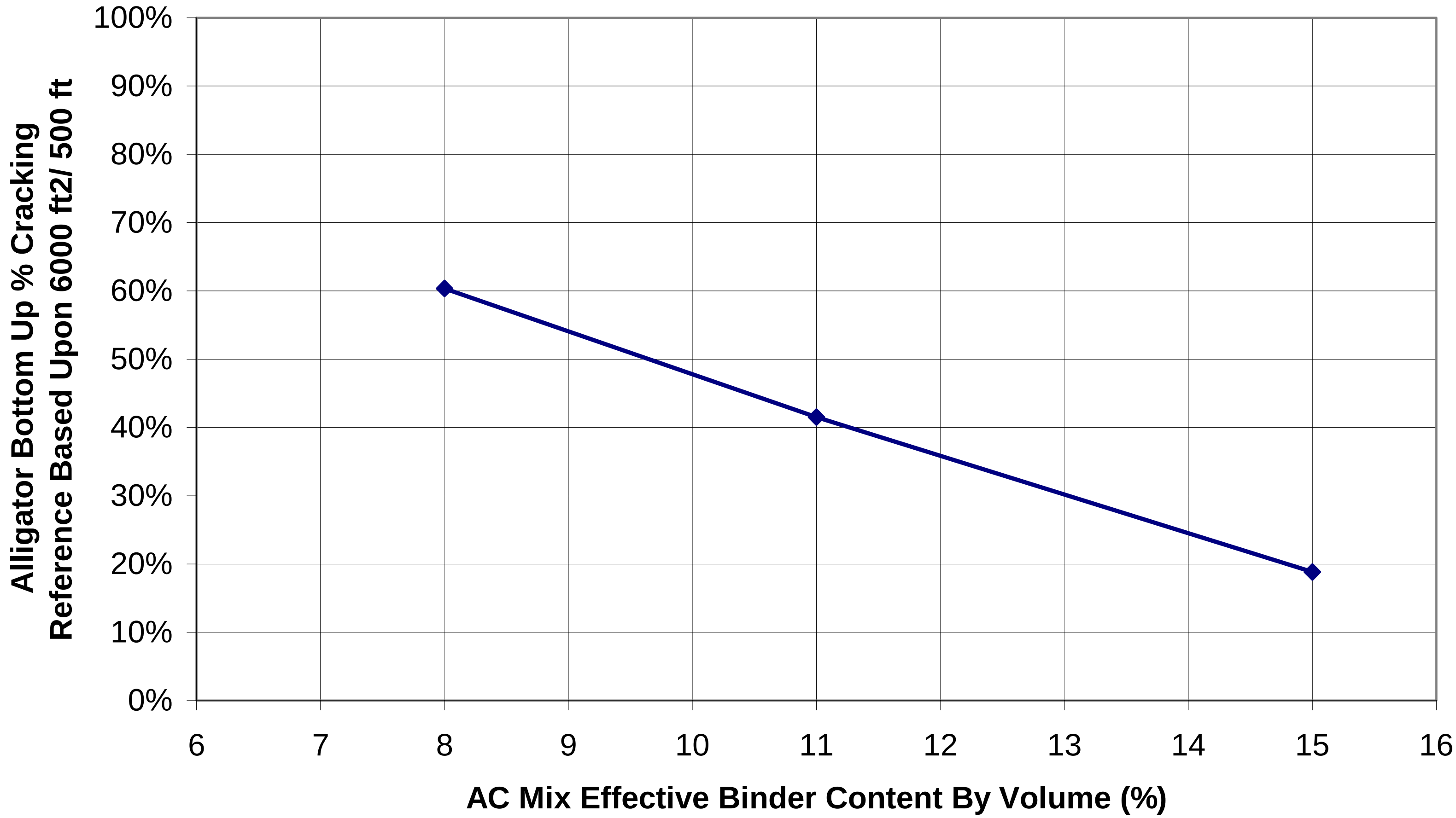

Figure 3.6-1 Effect of Percent AC Binder by volume on Alligator Fatigue Cracking

3.7 Influence of Depth to GWT on Fatigue (Alligator) Cracking

3.7.1 Objective

The objective of this section is to study the effect of depth to GWT on the amount of alligator (bottom- up) cracking.

3.7.2 Input Parameters

a. Traffic: High traffic volume (1000 AADTT)
b. Traffic Speed: 45 mph
c. Environment: Phoenix
d. Depth to GWT: 2, 4, 7 and 15 ft
e. Pavement Cross-Section: Three layered system as shown in Figure 2.1
f. Layer properties:
   - AC layer: 4 inches
   - AC Mix Stiffness: High Stiff Mixture as shown in Table 2.6 and Figure 2.2
   - Granular Base layer: Constant modulus = 38,000 psi.
   - Subgrade: Five different subgrade support values used (above GWT/ below GWT) (Mr=34,000/17,600; 25,000/13075; 18,000/10260, 10,000/5,860 and 6,000/2250 psi).
g. Depth to bedrock: No Bedrock present

3.7.3 Results

Figure 3.7-1 shows the percentage of alligator fatigue cracking after 10 years of loading for four levels of depth to GWT, for a variety of subgrade modulus materials.

3.7.4 Discussion of Results

These runs were conducted on pavement sections in which the granular base and subgrade moduli were fixed at the values shown above (i.e. no correction of moisture content using EICM). However, a subgrade layer was added below the GWT depth to reflect the saturated conditions of the subgrade. The saturated values were estimated from prior analysis of runs using the EICM models.

As a general observation, as would be expected, the alligator cracking distress decreases as the depth of the ground water table is increased. Also, as explained in a previous comparison, the alligator bottom-up cracking decreases as the subgrade modulus is increased. It can be observed that the most significant impact upon fatigue damage will occur when high GWT are found in weaker, clayey subgrades. There appears to be little impact of GWT location upon the magnitude of alligator cracking for higher subgrade modulus. For the problem input parameters, it appears that GWT depths, greater than 5 feet to 7 feet will not impact upon fatigue damage.

Higher GWT depth leads to saturation of the subgrade and hence reduces the subgrade modulus. If the difference between the saturated modulus below the GWT and the unsaturated modulus above the GWT is large enough, the GWT depth will cause significant changes in the alligator fatigue cracking.

One of the facts, the engineer should consider is that the sensitivity of subgrade support (modulus) to alligator cracking as large compared to the sensitivity of support modulus to permanent deformation (rutting). This is very much consistent to the sensitivity of PCC fatigue cracking to Westergaard's modulus of subgrade reaction value (k). As a consequence, even though the presence of the GWT does influence the in-situ moisture and hence modulus of the unbound base/subbase and subgrade materials; the resultant change of the in-situ unbound material modulus profile may be small, and it's impact upon the overall support modulus, and eventual fatigue cracking, is not overly sensitive to the final value. The sensitivity, however, will increase with poorer (lower) subgrade support values.

3.7.5 Summary and Conclusions

In general, the sensitivity of GWT to alligator cracking will be dependent upon the subgrade support encountered. As a general statement, fatigue damage will increase as the GWT moves closer to the surface. At depths greater than 5 feet to 7 feet, the influence of the GWT becomes very low. Finally, the impact of GWT is most significant for low modulus subgrade materials.

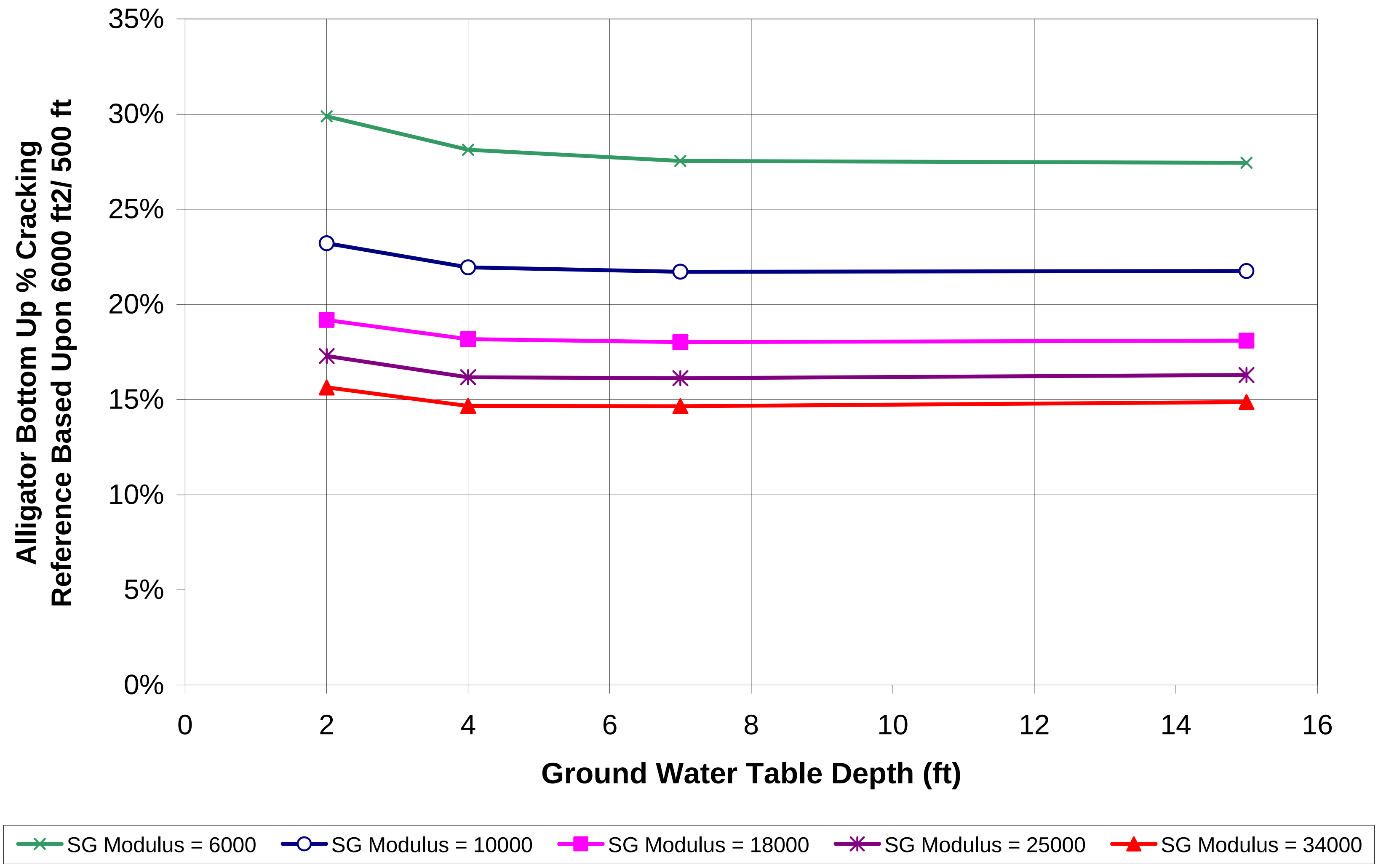

Figure 3.7-1 Effect of Depth to GWT on Alligator Fatigue Cracking

3.8 Influence of Truck Traffic Volume Upon Fatigue (Alligator) Cracking

3.8.1 Objective

The objective of this section is to investigate the influence of the truck traffic volume upon alligator fatigue cracking.

3.8.2 Input Parameters

a. Traffic Volume (AADTT): 100, 1000, 4000 and 7000
b. Traffic Speed: 45 mph
c. Environment: Oklahoma
d. Depth to GWT: Medium (7 ft)
e. Pavement Cross-Section: Three layered system as shown in Figure 2.1
f. Layer properties:
   - AC layer: 4 inches
   - AC Mix Stiffness: Medium Stiff Mixture as shown in Table 2.6 and Figure 2.2
   - Granular Base layer: As shown in Table 2.9 and Figure 2.1
   - Subgrade: Medium Support (Mr=15,000 psi) as shown in Table 2.9
g. Depth to bedrock: No Bedrock present

3.8.3 Results

Figure 3.11-1 shows the percentage of alligator fatigue cracking after 10 years of loading for four levels of truck traffic volume expressed in AADTT (Average Annual Daily truck Traffic). These levels of truck volumes approximately equate to: 200,000; 2,000,000; 15,000,000; and 100,000,000 ESALs respectively.

3.8.4 Discussion of Results

As one would intuitively surmise, the magnitude of the truck volume plays a very significant role upon the amount of alligator cracking that occurs for the pavement system having the 4" AC layer noted. As traffic volume (AADTT) increases, the amount of alligator fatigue cracking increases in a very significant fashion.

3.8.5 Summary and Conclusions

Increasing the truck traffic volume (AADTT) increases the amount of alligator fatigue cracking. In essence, the parameter of truck traffic (volume), or even ESALs is an extremely sensitive parameter to alligator cracking. The rate of change of alligator cracking with truck traffic volume is nearly linear across all ranges of truck volume. The trend becomes slightly non-linear for the very high level of truck traffic investigated in this study.

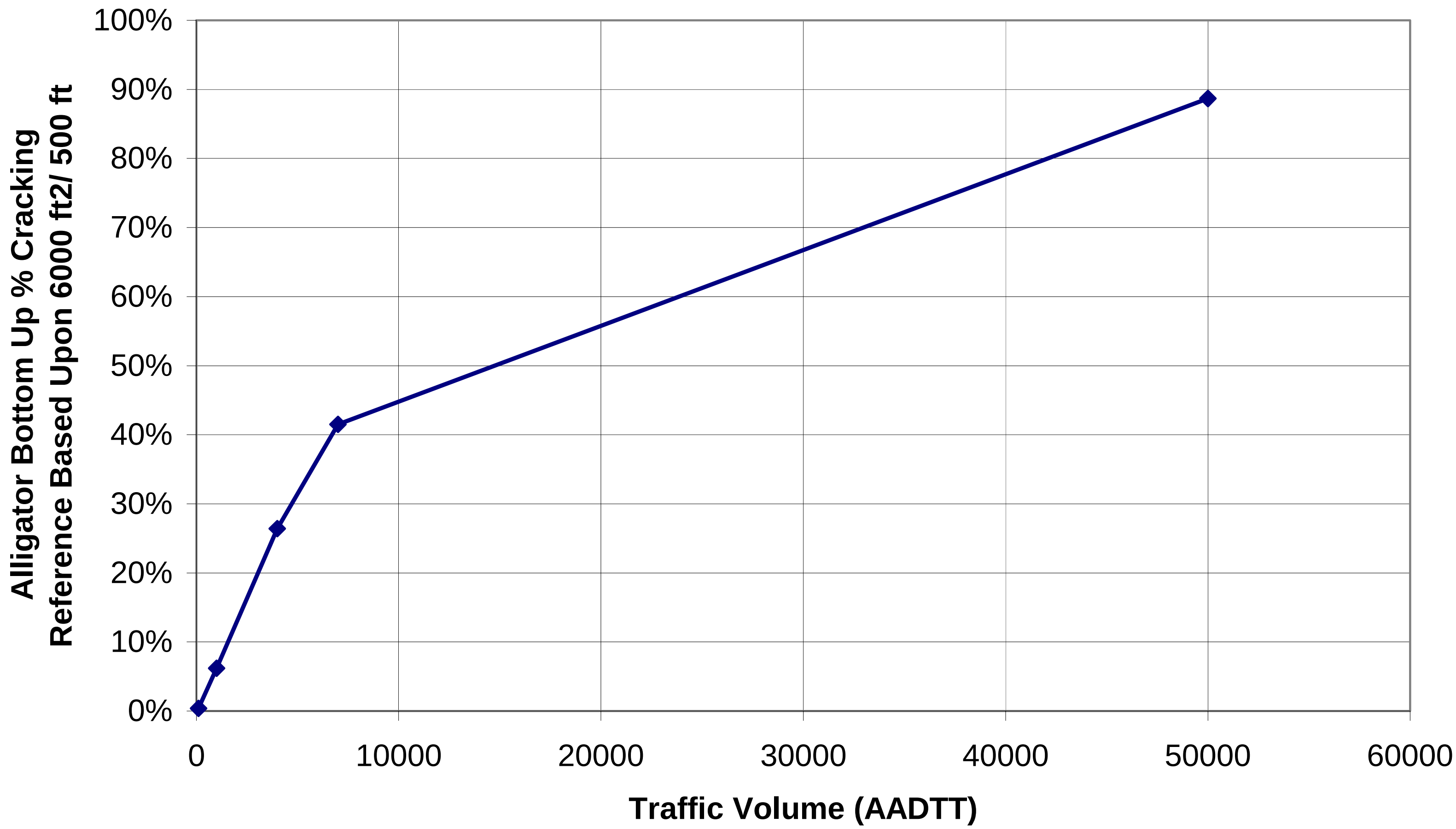

Figure 3.8-1 Effect of Truck Traffic Volume on Alligator Fatigue Cracking (Hac=4 in)

3.9 Influence of Traffic Speed Upon Fatigue (Alligator) Cracking

3.9.1 Objective

The objective of this section is to study the effect of traffic speed on alligator fatigue cracking.

3.9.2 Input Parameters

a. Traffic: High traffic volume (7000 AADTT)
b. Traffic Speed: 2, 25, 45 and 60 mph
c. Environment: Oklahoma (for variable level subgrade support study); Minnesota (for supplemental studies of Hac thickness effect)
d. Depth to GWT: Medium (7 ft)
e. Pavement Cross-Section: Three layered system as shown in Figure 2.1
f. Layer properties:
   - AC layer: 4 inches
   - AC Mix Stiffness: Medium Stiff Mixture as shown in Table 2.6 and Figure 2.2
   - Granular Base layer: As shown in Table 2.9 and Figure 2.1
   - Subgrade: Four different subgrade support values for variable support study (Mr=30,000; 15,000; 8,000 and 3,000 psi) as shown in Table 2.9; Mr=15,000 psi used in supplementary Hac thickness study)
g. Depth to bedrock: No Bedrock present

3.9.3 Results

Figure 3.9-1(a thru c) show the results of the sensitivity study relative to traffic speed upon alligator cracking. Figure 3.9-1a contains results of the percentage of alligator fatigue cracking after 10 years of loading for the four levels of traffic speed (2 mph to 60 mph), and the four levels of subgrade support noted in section 3.9.2. Figures 3.9-1b and c, provide the results of the study for two different thickness levels of AC: 1" and 8" for the cold temperature condition associated with a subgrade modulus of 15,000 psi and the use of a "medium" AC stiffness.

3.9.4 Discussion of Results

Hac=4"; Multiple Subgrade Support Study:

For the 4" AC layer pavement system, it can be observed that the influence of operational vehicle speed has a very minor effect upon the alligator cracking observed, across all levels of subgrade support. One can detect, however, a very minor decrease in alligator cracking as the vehicle speed is increased. This result is fundamentally correct, especially as the thickness of the AC layer is increased. The reason for this is as follows. As the vehicle speed is increased, the load time of the stress pulse acting on the AC layer becomes smaller. Thus, with a higher speed, the time of the stress load is diminished, at a given temperature. This leads to a slight increase in the E* of the AC layer material (refer to AC Master Curve). As the E* is increased, a slightly lower tensile strain then occurs in the AC bound layer. This slightly lower tensile strain will then lead to a slightly reduced degree of damage, and hence a slight increase in the fatigue resistance of the mix. This aspect is eventually translated to a small decrease in alligator cracking (slightly less damage) as the vehicle operational speed is increased. This phenomenon is clearly shown in the figure.

While the previous discussion is based upon the events surrounding a 4" AC layer; it is important to also understand the implications of increased vehicle speed upon fracture of very thin (e.g. 1") AC layers. Referring to Figure 3.1-1 for the alligator cracking of thin AC layers; it can be seen that, for both conditions of cracking, the presence of very stiff (high E*) mixtures leads to a greater degree of cracking. Since increases in the vehicle speed will cause an increase in the E* of the AC layer, the consequence of this is the fact that a greater degree of damage may occur within the thin AC layer as the vehicle speed is increased. This is verified in the ensuing paragraphs.

Hac=1" and 8"; Cold Climatic Site

Figures 3.9-1b and c reflect the results for the influence of traffic speed upon alligator cracking for a thin AC layer (Fig 3.9-1b) as well as a thicker 8" AC layer (Fig 3.9-1c), for a single subgrade support modulus of Mr=15,000 psi in a cold environmental site. For the 1" thin AC layer; it can be seen that increasing the traffic speed tends to increase the alligator cracking (slight increase for the example inputs used in the study). This is a very logical result due to the fact that thin AC layers, anything that will cause an increase in the E* of the AC mixture, will cause an increase in the fatigue damage and cracking that is observed. Increasing the traffic speed actually results in a shorter load stress pulse (time of loading) in the AC layer. This has a tendency, at any given temperature, to increase the mix E* (refer to master curve and reduced time effect upon the E*).

As the AC layer thickness is substantially increased (Hac=8" in Fig.3.9-1c); it can be observed that the amount of alligator damage and cracking, decreases with increasing speed. This reverse trend from the thin 1" AC layer, is also logical, as increasing the vehicular speed causes an increase in the E*, a decrease in the tensile strain and less damage (alligator cracking) to the pavement system. Finally, it should be noted that the sensitivity of speed to fatigue damage is not overly significant. In all actuality, the specific changes in fatigue damage is a complex mechanism and very much a function of the specific input parameters of a given pavement system.

3.9.5 Summary and Conclusions

As a general conclusion, changes in the vehicular operational speed on the amount of alligator cracking in a pavement system may not be very large. For very thin AC layer pavement systems, the amount of fatigue damage and cracking will increase as the speed of the loading system is also increased. For very thick pavements, the reverse will occur and slightly less fatigue damage may be present at higher vehicle speeds.

At intermediate (4" AC layer thicknesses); the influence of traffic speed upon fatigue damage is not overly significant, particularly across a broad range of AC layer thicknesses.

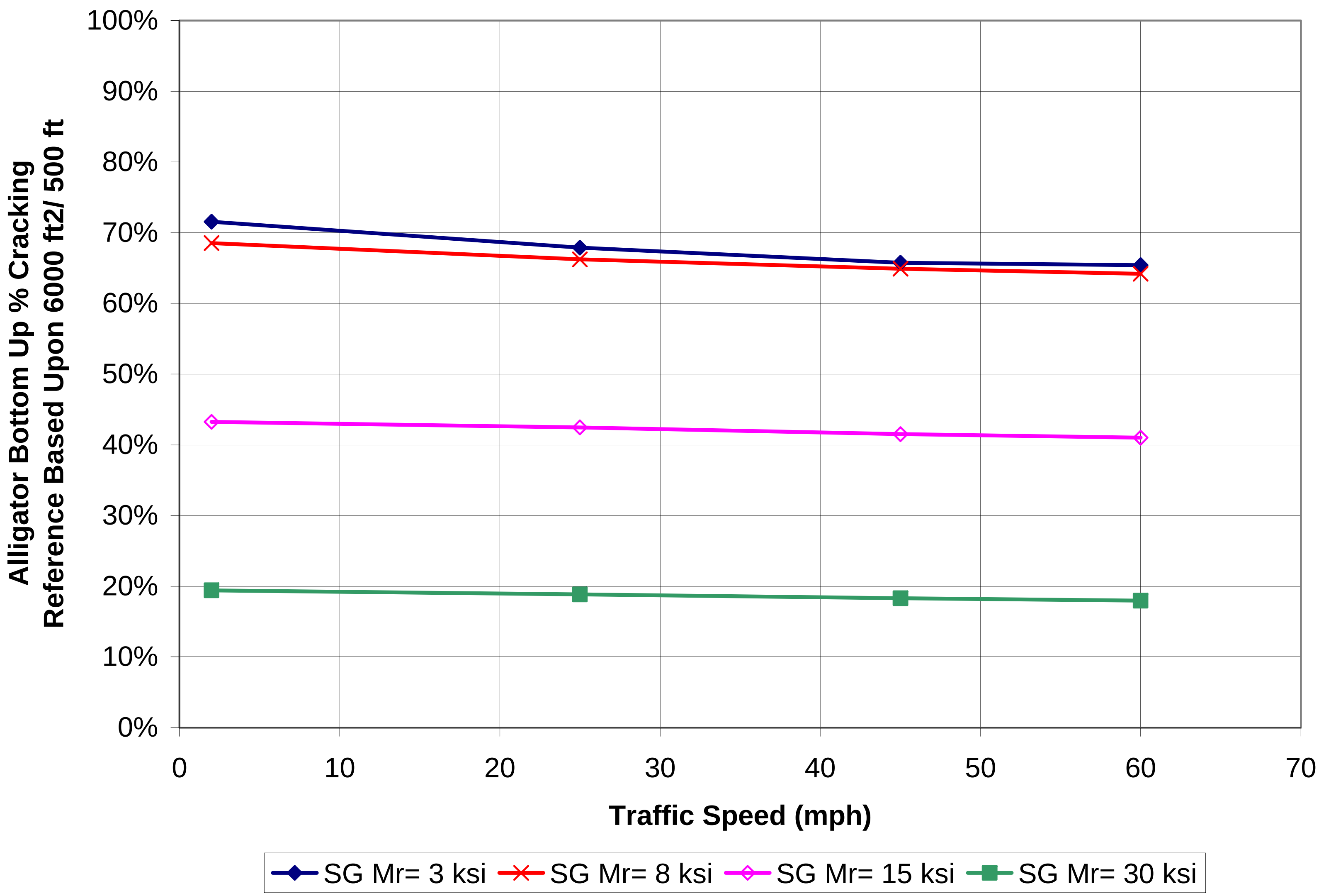

Figure 3.9-1a Effect of Traffic Speed on Alligator Fatigue Cracking (H_{ac} =4”, Moderate Climate)

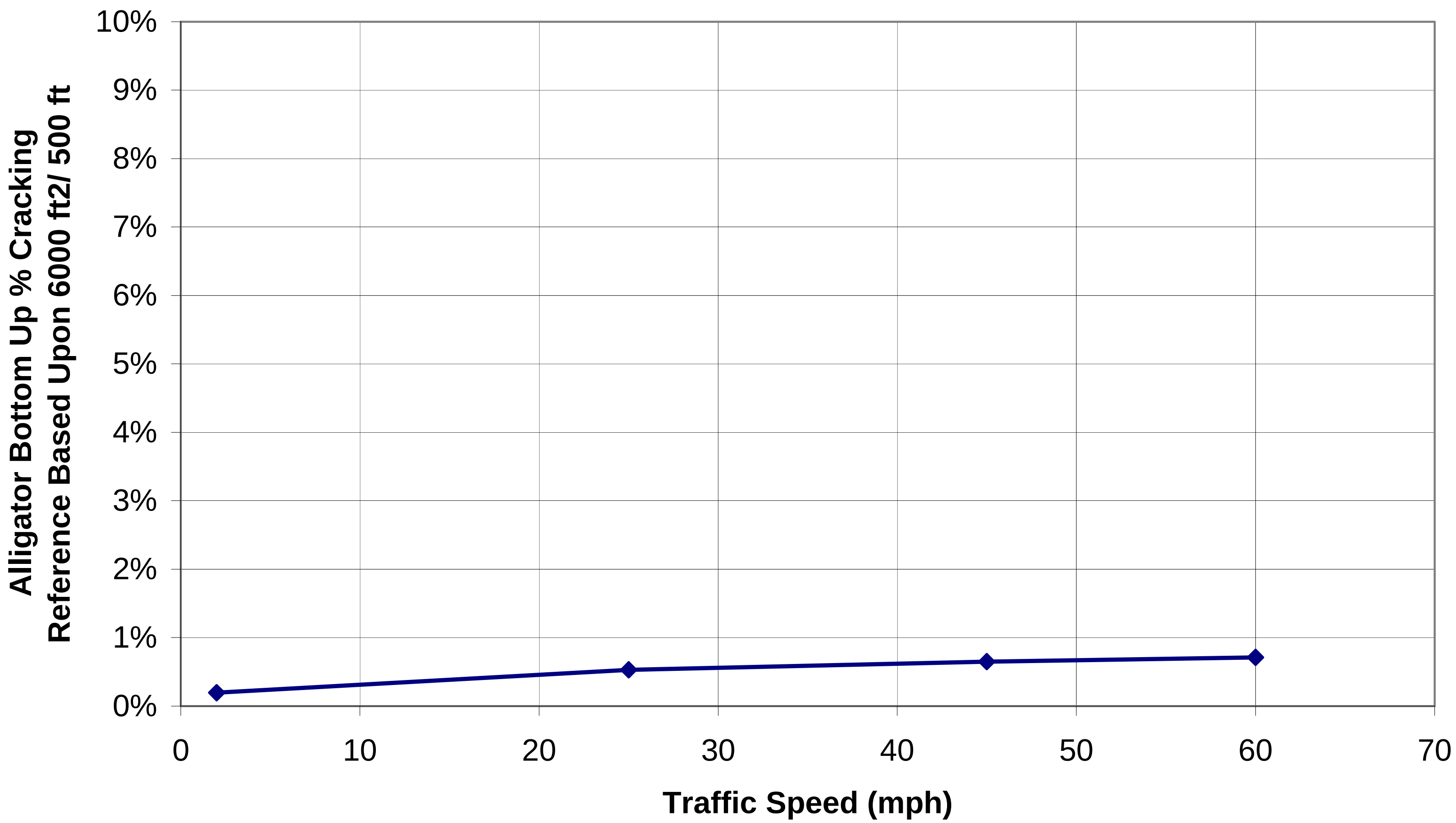

Figure 3.9-1b Effect of Traffic Speed on Alligator Fatigue Cracking (H_{ac} =1”, Cold Climate)

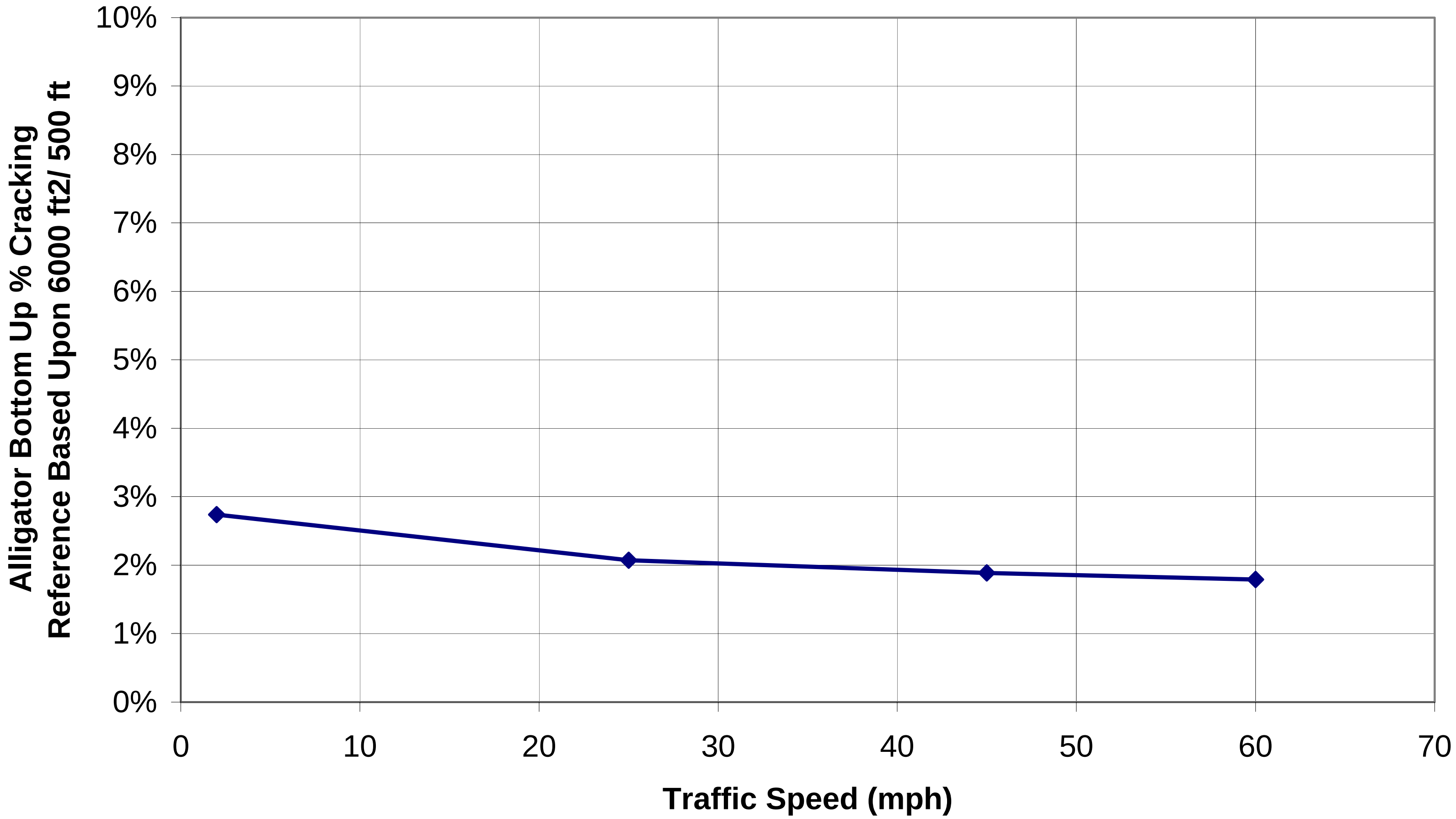

Figure 3.9-1c Effect of Traffic Speed on Alligator Fatigue Cracking (H_{ac} =8”, Cold Climate)

3.10 Influence of Traffic Analysis Level Upon Fatigue (Alligator) Cracking

3.10.1 Objective

The objective of this section is to investigate the influence of Hierarchical Traffic Level used in the analysis upon the amount of alligator fatigue cracking.

3.10.2 Input Parameters

a. Traffic Volume: See discussion in 3.13.3 "Results" section below
b. Traffic Speed: 45 mph
c. Environment: Oklahoma (61 deg F)
d. Depth to GWT: Medium (7 ft)
e. Pavement Cross-Section: Three layered system as shown in Figure 2.1
f. Layer properties:
    - AC layer: 4 inches
    - AC Mix Stiffness: Medium Stiff Mixture as shown in Table 2.6 and Figure 2.2
    - Granular Base layer: As shown in Table 2.9 and Figure 2.1
    - Subgrade: Medium Support (Mr=15,000 psi) as shown in Table 2.9
g. Depth to bedrock: No Bedrock present

3.10.3 Results

Figure 3.10-1 shows the impact of the Hierarchical Traffic Level selected upon the relationship of the percentage of alligator fatigue cracking (after 10 years of loading) for a range of traffic volumes (distributions). In this plot, four specific traffic distributions (volumes) were investigated. For the Traffic Level 1 approach, the actual traffic load axle spectrums were used as input into the program. The load spectrum approach used the input traffic assumptions noted in Tables 2.2 to 2.5. The cracking results using the Level 1 approach, for each of the four traffic volumes, is denoted as the "Load Spectra" results in the plot. For each of the four axle load spectrum distributions; the mixture axle type- load combinations were then transformed into Equivalent 18 Kip Single Axle Load repetitions (ESALs) through the use of conventional AASHTO truck damage factors, defined at a pt=2.5 and SN=5. The approximate cumulative 10-year ESAL values have been noted in Table 2.1.

3.10.4 Discussion of Results

The alligator fatigue cracking results shown in Figure 3.10-1 clearly indicate that the use of actual traffic load spectra, in the structural distress prediction model, results in a difference in predicted cracking, compared to the use of the empirical ESAL approach to traffic that has been historically used in pavement design. For the problem investigated, the traffic axle load spectra approach (Level 1) appears to yield about 3% to 7% more cracking compared to the use of E18KSAL's. This implies that the level 1 approach, based upon the actual load spectra, provides more damaging (fatigue) predictions than the conventional ESAL approach.

3.10.5 Summary and Conclusions

The use of a Level 1 traffic approach, based upon the actual traffic load spectra, yields a higher level of alligator cracking compared to the classical use of E18KSAL's.

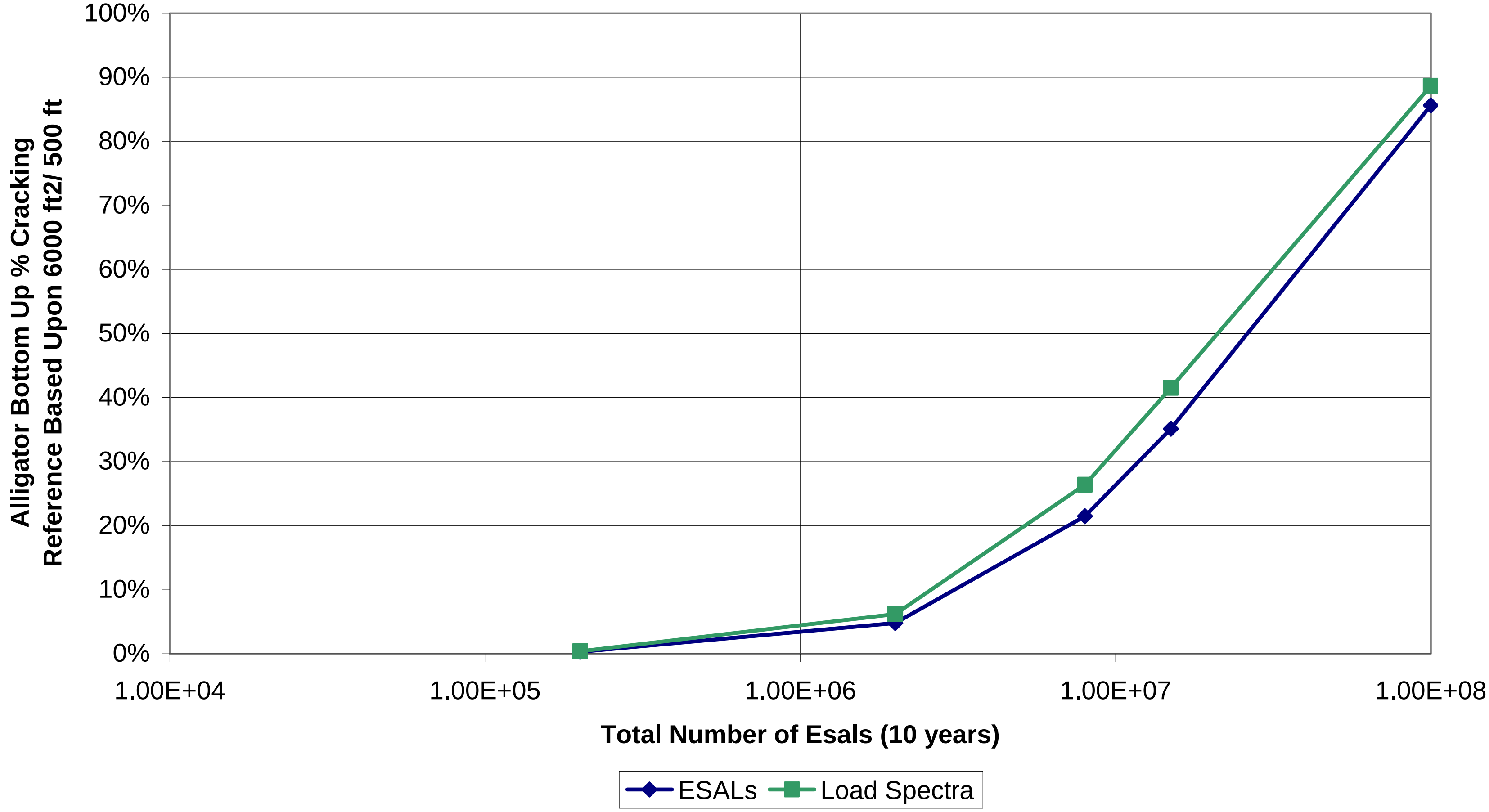

Figure 3.10-1 Effect of Traffic Analysis Level upon Alligator Fatigue Cracking

3.11 Influence of MAAT Upon Fatigue (Alligator) Cracking

3.11.1 Objective

The objective of this section is to study the effect of MAAT (actual site environment) on the alligator fatigue cracking.

3.11.2 Input Parameters

a. Traffic Volume: Medium (7000 AADTT)
b. Traffic Speed: 45 mph
c. Environment: (MAAT): Minnesota (46 deg F); Oklahoma (61 deg F) and Phoenix (74 deg F)
d. Depth to GWT: Medium (7 ft)
e. Pavement Cross-Section: Three layered system as shown in Figure 2.1
f. Layer properties:
    - AC layer: 1,4, 8 and 12 inches
    - AC Mix Stiffness: High, Medium and Low Mixture Stiffnesses as shown in Table 2.6 and Figure 2.2
    - Granular Base layer: As shown in Table 2.9 and Figure 2.1
    - Subgrade: Medium Support (Mr=15,000 psi) as shown in Table 2.9
g. Depth to bedrock: No Bedrock present

3.11.3 Results

The full results of this sensitivity analysis are shown in Figures 3.11-1(a thru d). Each figure represents the relationship of predicted alligator cracking as a function of a specific level of AC layer thickness (Hac= 1, 4, 8 and 12"). The percentage of alligator fatigue cracking shown reflects 10 years of loading for the three levels of MAAT investigated.

3.11.4 Discussion of Results

The results shown are quite important relative to the selection of the appropriate level of AC mix stiffness (E*) as a function of the thickness of the AC layer. Theses results can best be interpreted for each AC thickness level presented in the analysis.

<u>Hac=1":</u> Referring to Figure 3.11-1a (Hac=1"); it can be observed that the amount of fatigue cracking (damage) is always increased as the MAAT is also increased. This is true for all mixture stiffness values (E*). This result is very logical because as the MAAT increases, larger pavement temperatures will occur. This is turn, will lead to lower in-situ AC stiffnesses (dynamic moduli), which in turn causes greater tensile strains, a lower number of repetitions to failure (Nf) and a greater degree of damage (alligator cracking), regardless of the original AC mix stiffness master curve (E*).

The second significant finding shown in the figure supports the discussion of study 3.1. As can be observed, the degree of alligator cracking that occurs is extremely sensitive to the AC mixture stiffness (E*). For thin AC layers, the greater the mixture stiffness, the greater the degree of alligator cracking. In fact, for the very thin AC layer, it can be observed that there is a very strong degree of sensitivity of the AC E* stiffness to the amount of cracking that occurs.

Hac=4": The influence of increasing the AC thickness from a 1" layer to a 4" layer is illustrated in Figure 3.11-1b. It is observed that an identical conclusion, relative to the significance of the MAAT upon cracking, is noted for the 4" AC layer, compared to the 1" AC layer. The explanation of this result is the same as what was presented for the 1' AC layer. All increasing the temperature at the site will accomplish is to increase the tensile strains, regardless of the mixture stiffness.

In regards to the impact of the AC mixture stiffness level at the 4" layer thickness level , it can be observed that the sensitivity of E* to the amount of alligator cracking, is nowhere near as significant as it was for the 1" layer thickness. Nonetheless, even at the 4" AC thickness level, there is a slight, but noticeable, trend of the mixture E* value upon cracking. For the conditions noted in this example, it is observed that more alligator cracking will occur with the stiffer (higher) E* AC mixtures, compared to the mixtures with a lower E* stiffness relationship.

Hac=8": As the thickness of the AC layer is increased from 4" to 8"; the sensitivity of E* and MAAT is shown in Figure 3.11-1c. It is again obvious that the influence of warmer design sites upon an increased level of alligator cracking is identical to the conclusion already noted for the 1" and 4" AC layers. As previously noted, this is not surprising and the explanation provided in the previous paragraphs are truly applicable for any level of AC thickness.

At the Hac=8" level; it can be noted that there is very little, if any effect of the AC mixture stiffness upon the amount of alligator cracking observed.

Hac=12": The influence of the MAAT and E*, upon alligator cracking for the thick (12") AC layer; is presented in Figure 3.11-1d. It is observed that increasing the MAAT will lead to an increase in the amount of alligator cracking; an identical conclusion noted for all of the three prior thickness levels.

Regarding the influence of the E* upon the degree of cracking, it can be observed that the influence of E* tends to reverse itself from the previous thickness levels and that a high E* value generally tends to yield less damage than mixtures with lower stiffnesses. However, the relative change in damage may be “academic” because damage and hence fatigue cracking, will be very small at relatively large thicknesses of AC.

3.11.5 Summary and Conclusions

Regardless of the thickness of the AC layer, the amount of fatigue damage and alligator cracking will increase with increasing Mean Annual Air Temperature at the design site. This is true for whatever level of AC mixture stiffness is utilized in the pavement structure.

However, the actual thickness of the AC layer tends to play a very critical role in defining the optimum benefit (lowest amount of alligator cracking damage) for the specific mix in question. As a general rule, for very thin AC layers; the use of a very stiff AC mixture will result in maximum fatigue damage and cracking. As the AC layer thickness is increased to levels of 10" - 12+", the use of stiff mixtures (high E* values) is preferable and will lead to a minimum of fatigue damage and alligator cracking.

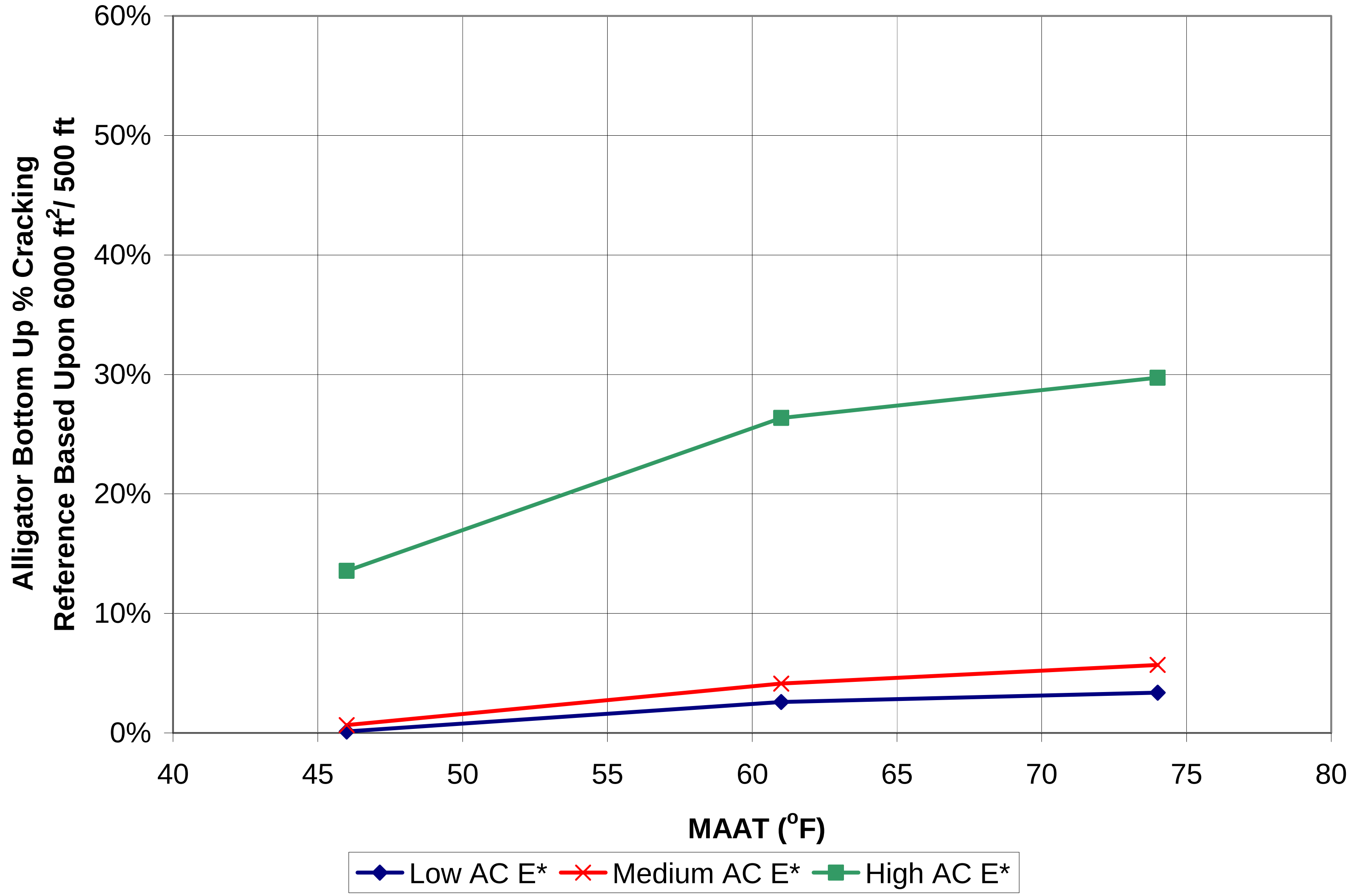

Figure 3.11-1a Effect of MAAT on Alligator Fatigue Cracking (H_{ac} =1")

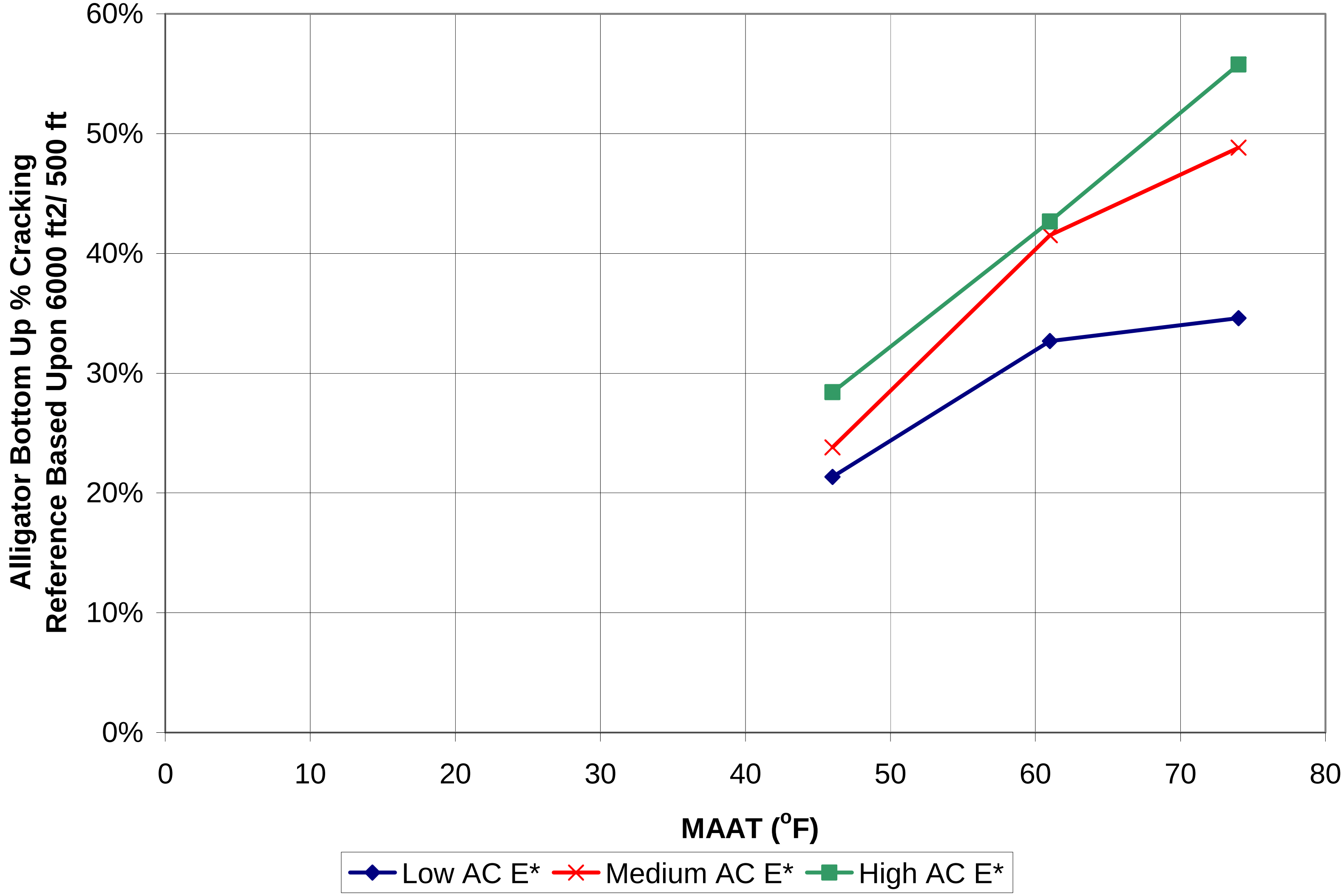

Figure 3.11-1b Effect of MAAT on Alligator Fatigue Cracking (H_{ac} =4”)

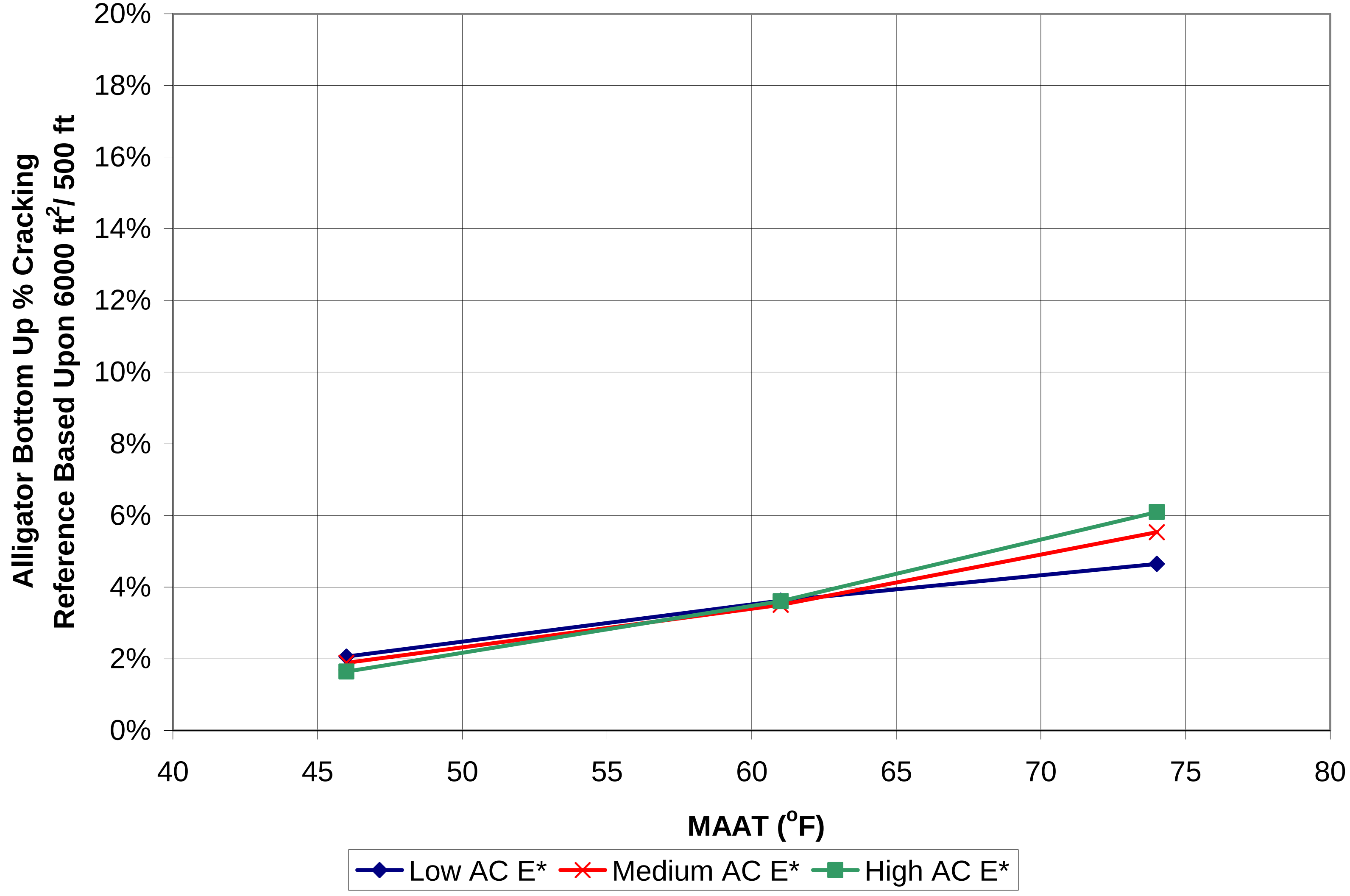

Figure 3.11-1c Effect of MAAT on Alligator Fatigue Cracking (H_{ac} =8")

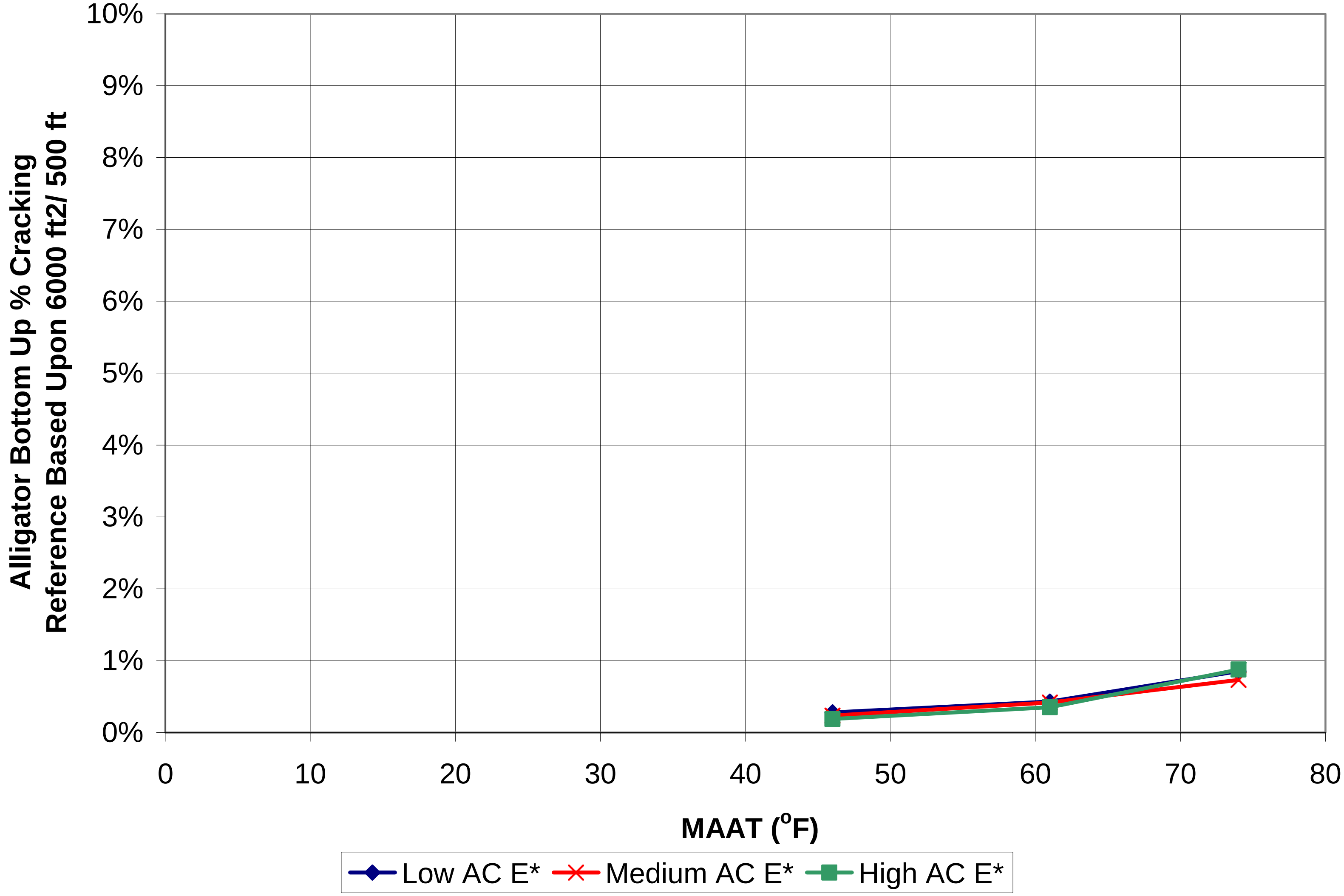

Figure 3.11-1d Effect of MAAT on Alligator Fatigue Cracking (H_{ac} =12”)

3.12 Influence of Bedrock Depth upon Fatigue (Alligator) Cracking

3.12.1 Objective

The objective of this section is to study the effect of changing the depth of bedrock under a flexible pavement upon the amount of alligator fatigue cracking.

3.12.2 Input Parameters

a. Traffic: High traffic volume (7000 AADTT)
b. Traffic Speed: 45 mph
c. Environment: Oklahoma
d. Depth to GWT: medium (7 ft) for bedrock depths 10 and 20 ft; GWT at top of Bedrock for all depths less than 5 ft
e. Pavement Cross-Section: Three layered system as shown in Figure 2.1
f. Layer properties:
   - AC layer: 4 inch
   - AC Mix Stiffness: Medium as shown in Table 2.6 and Figure 2.2
   - Granular Base layer: As shown in Table 2.9 and Figure 2.1
   - Subgrade: Two subgrade support values used (Mr=30,000 and 3,000 psi) as shown in Table 2.9
g. Depth to bedrock: 3', 4', 5', 6’,7’, 12' and 22' (from top of pavement): Ebr= 750,000 psi

3.12.3 Results

Figures 3.12-1 shows the percentage of alligator fatigue cracking (after 10 years of loading) as a function of the depth of the Bedrock layer, for the two levels of subgrade support evaluated.

3.12.4 Discussion of Results

The results presented in the figure very clearly demonstrate that the presence of bedrock near the surface of the pavement can have a very significant effect upon the alligator fatigue cracking that may occur in a pavement system. While the figure is applicable for only one specific pavement cross-section example; it can be seen that the bedrock will generally influence softer subgrade support values (Mr=3,000 psi) to greater depths. For the example shown, a bedrock layer within 10 to 12' of the subgrade surface, for a subgrade Mr= 3000 psi, appears to be a typical bedrock depth that one would have to be concerned about. It can be observed that for the case of a much stronger subgrade support value (Mr=30,000 psi); this effective bedrock depth decreases to about 2 to 3'.

As the bedrock layer is closer to the surface, the deep stiff bedrock layer will tend to start decreasing the tensile strains at the bottom of the AC layer. In fact, as the bedrock layer gets to within several feet of the subgrade; it is apparent that the neutral axis of the composite pavement may actually shift below the last AC layer and cause a compressive state of stress (strain), rather than tension to exist at the bottom of the AC layer. Once this occurs, this phenomenon will result in having little to no alligator cracking present in the pavement system.

3.12.5 Summary and Conclusions

The presence of bedrock within a flexible pavement cross-section may influence the magnitude of alligator fatigue cracking that may occur. In general, the closer a bedrock layer comes to the subgrade surface, the less fatigue fracture that may occur. The "critical bedrock depth", at which there is no more influence upon fatigue cracking will vary as a function of many properties of the cross-section. For example, a pavement with a 4" AC layer, will have a "critical bedrock depth" of only 2' to 3" for a subgrade support value of Mr=30,000 psi. In contrast, this "effective bedrock depth" will increase to as large as 10' to 12' if the subgrade support is decreased to Mr=3,000 psi.

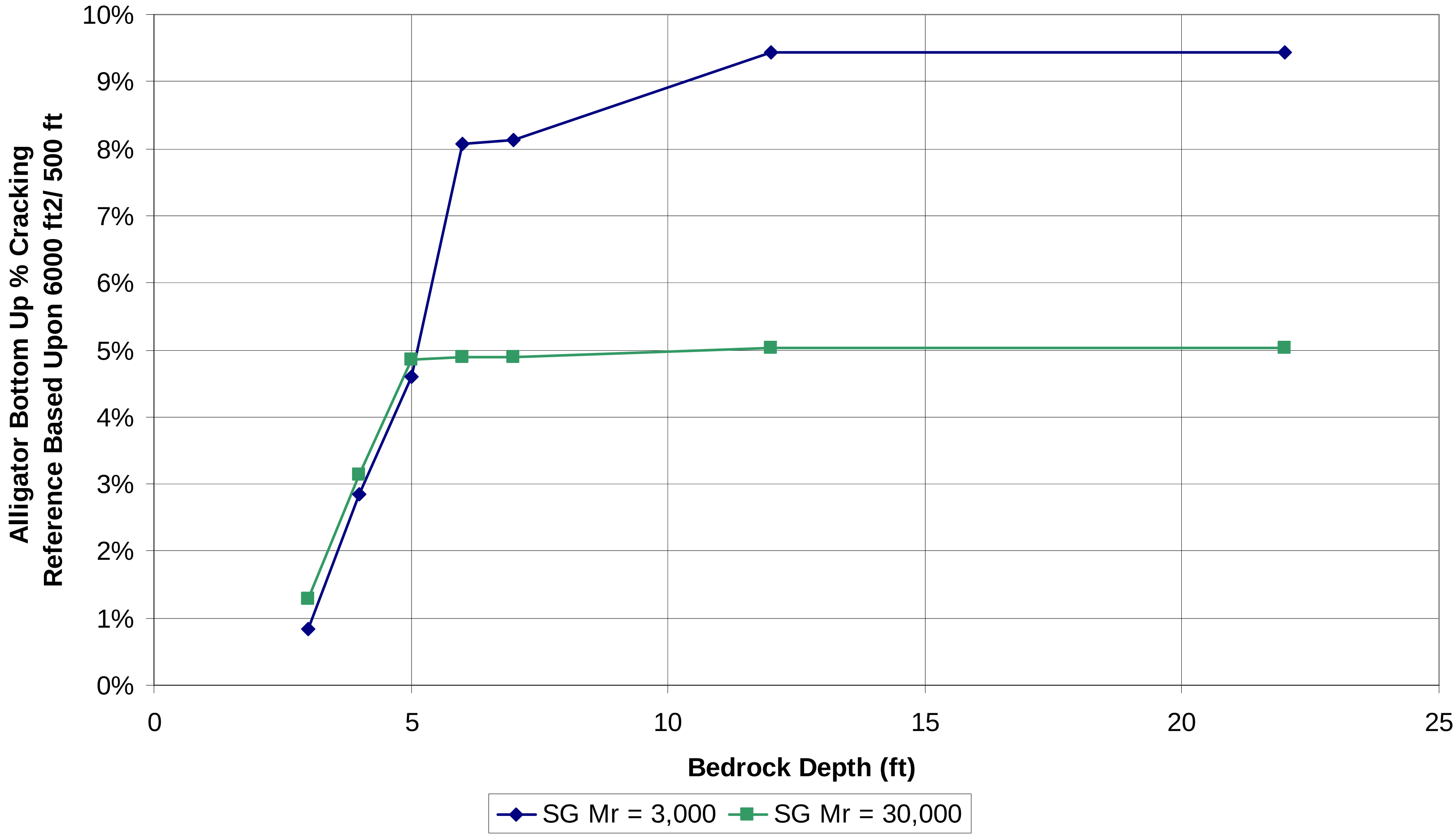

Figure 3.12-1 Effect of Bedrock Depth Upon Alligator Fatigue Cracking (Hac=4", Moderate Climate

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Guide for Mechanistic-Empirical Design
OF NEW AND REHABILITATED PAVEMENT STRUCTURES

FINAL DOCUMENT

APPENDIX II-3:
SENSITIVITY ANALYSIS FOR ASPHALT CONCRETE FATIGUE LONGITUDINAL SURFACE CRACKING

NCHRP

Prepared for
National Cooperative Highway Research Program
Transportation Research Board
National Research Council

Submitted by
ARA, Inc., ERES Division
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Disclaimer

This is the final draft as submitted by the research agency. The opinions and conclusions expressed or implied in this report are those of the research agency. They are not necessarily those of the Transportation Research Board, the National Research Council, the Federal Highway Administration, AASHTO, or the individual States participating in the National Cooperative Highway Research program.

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Research into the subject area covered in this Appendix was conducted at ASU. The authors of this Appendix are Dr. M.W. Witczak, Mr. M. M. El-Basyouny, and Mr. S. El-Badawy.

Foreword

This appendix is the third in a series of three volumes on Calibration of Fatigue Cracking Models for Flexible Pavements. This volume concentrates on the sensitivity analysis for asphalt concrete fatigue longitudinal surface cracking.

The other volumes are:

Appendix II-1:	Calibration of Fatigue Cracking Models for Flexible Pavements
Appendix II-2:	Sensitivity Analysis for Asphalt Concrete Fatigue Alligator Cracking

General Table of Content

Appendix II-3

Sensitivity Analysis for AC Fatigue Longitudinal Surface Cracking

APPENDIX II-3: SENSITIVITY ANALYSIS FOR AC FATIGUE LONGITUDINAL SURFACE CRACKING

1 Introduction and Objectives

The objective of this major component of the overall Design Procedure sensitivity study is to investigate how the prediction of longitudinal surface (top down) fatigue cracking is influenced by changes in magnitude of several different key input variables. To study the sensitivity of these input parameters on fatigue cracking the Design Guide computer program was run using several factorial combinations of the input parameters shown in Table 2.1. Unless specifically noted in the specific sensitivity write-up; most of the computer runs used parameters that were typically related to the "Medium" levels shown in the table.

In general, the sensitivity study of fatigue cracking was not intended to cover a complete full factorial of all parameters, but rather to investigate the effect of varying one parameter at a time, while keeping as many of the other variables to be constant input parameters.

The independent parameter that is used for the Design Guide prediction for the longitudinal surface (top down) fatigue distress is the amount of cracking. The specific value used as the program output for the longitudinal fatigue cracking is described as follows:

- Longitudinal cracking (top down) is computed in the program as the length (in ft) of longitudinal cracking, per 500 ft / lane, in both wheel paths. Thus the maximum amount of cracking would be 1000 ft / 500 ft / lane. The cracking percentage limits vary between 0 and 100%. As an example, if the program would predict a longitudinal cracking value of 400 ft / 500 ft / lane; then the percent longitudinal cracking (percent damage) would be 400 ft / 1000 ft = 40.0%.

In order to investigate the overall sensitivity of key parameters to fatigue cracking; a series of individual studies were performed. Each separate study had it's own unique parametric objective. The sensitivity analysis for fatigue cracking covered the following items shown below. The paragraph where the sensitivity study outcome is reported and discussed is also shown in the following list:

Paragraph - Study ID

3.1 Influence of AC Mix Stiffness upon Fatigue (Longitudinal) Cracking (Thin AC Layers)

3.2 Influence of AC Mix Stiffness upon Fatigue (Longitudinal) Cracking (Thick AC Layers)

3.3 Influence of AC Thickness upon Fatigue (Longitudinal) Cracking

3.4 Influence of Subgrade Modulus upon Fatigue (Longitudinal) Cracking

3.5 Influence of AC Mix Air Voids upon Fatigue (Longitudinal) Cracking

3.6 Influence of Asphalt Content (Effective Bitumen Volume) upon Fatigue (Longitudinal) Cracking

3.7 Influence of Depth to GWT on Fatigue (Longitudinal) Cracking

3.8 Influence of Truck Traffic Volume upon Fatigue (Longitudinal) Cracking

3.9 Influence of Traffic Speed upon Fatigue (Longitudinal) Cracking

3.10 Influence of Traffic Analysis Level upon Fatigue (Longitudinal) Cracking

3.11 Influence of MAAT upon Fatigue (Longitudinal) Cracking

3.12 Influence of Bedrock Depth upon Fatigue (Longitudinal) Cracking

Prior to presenting the sensitivity report results; the following section of this report describes the general input parameters (and ranges of variables) that have been utilized in the study.

2 Major Program Input Parameters Used in Study

2.1 Introduction

To study the effect of the desired sensitivity input parameter on top-down fatigue cracking, the major pavement design parameters were usually selected from one of three different levels of the parameter under study (Low, Medium and High). In certain special cases, a fourth level was employed to insure that an adequate range of the variable examined could be evaluated for the sensitivity study. In general, the majority of program runs were conducted using the "Medium levels" of all of the input variables, while varying the major parameter whose sensitivity was being examined. However, in some cases, traffic levels using a "High approach" were used to insure that adequate quantitative cracking levels would be obtained in the sensitivity runs. Table 2.1 shows the different input parameters used in this study and the three to four different levels for each parameter that were eventually investigated. Specifics concerning all of these input values are explained in the following sections.

2.2 Design Parameters and Pavement Structure

For the longitudinal surface fatigue sensitivity analysis, only the deterministic analysis was used in the study. The design life selected for each program run was 10 years. This was simply selected to minimize the computational running time required for the entire sensitivity effort. The granular base construction completion date was set two months earlier than the asphalt construction completion date for all problems, while the traffic opening date was set to be the same as the asphalt construction completion date.

A simple conventional flexible pavement structure was used in the study. The structure is a three-layer pavement system with a single asphalt concrete layer, an unbound granular base layer (10 inches thick) and a subgrade. Figure 2.1 shows the pavement structure used in the study. The asphalt layer thickness was varied from 1 - 12 inches to study the effect of AC thickness on the fatigue cracking. However, the thickness of the unbound granular base was fixed at 10 inch, for all problems analyzed.

2.3 Traffic

Two traffic methods were eventually used in the study: a general traffic module using the load spectrum (Level 1 type of analysis) and a classical 18 kip ESAL approach. The traffic volume was expressed by the average annual daily truck traffic (AADTT) selected to represent a very high traffic volume (50,000 daily truck), high truck traffic (7000 daily trucks), medium high traffic (4000 daily trucks), medium traffic (1000 daily trucks) and a low traffic (100 daily trucks). The general 10-year E18KSAL repetitions for these traffic levels are approximately: 100 million, 15 million, 8 million, 2 million and 200,000. The rest of the traffic parameters were set to the default values given by the software.

Tables 2.2 to 2.5 show the values of the various traffic parameter inputs used in this study. Information regarding the general traffic parameters (Table 2.2), AADTT distributions by vehicle class (Table 2.3), number of axles per truck (Table 2.4) and the axle configurations (Table 2.5) is illustrated. The monthly adjustment factors for traffic were set at 1; while the standard deviation of traffic wander was taken to be 10 inches. Finally, no traffic growth was considered in the study.

2.4 Climate

Three different climatic regions were selected in the sensitivity study of fatigue cracking. The climatic stations were selected to cover a broad range of US temperature conditions (cold, intermediate and hot region). One city was selected from each region to represent the climatic region. The cities were Minneapolis (Minnesota) for the cold climate, Oklahoma City (Oklahoma) for the intermediate climate and Phoenix (Arizona) for the hot weather. The mean annual air temperatures (MAAT) for these three stations were 46.1, 60.7 and 74.4 ºF, respectively.

Table 2.1 Parameters Used in the Sensitivity Runs

	Very Low	Low (L)	**Medium (M)**	Medium High	High (H)	Very High
Traffic Volume – AADTT (Vehicle/Day)		100	**1000**	4000	7000	50,000
(10 years) 18 Kips ESALs		$2*10^5$	$\mathbf{2*10^6}$	$\mathbf{8*10^6}$	$1.5*10^7$	$1.0*10^8$
Facility Type (Operating Speed (mph))	Intersection (2.0)	Urban Streets (25)	**State Primary (45)**		Interstate (60)	
Location (MAAT)		Minnesota (46.1ºF)	**Oklahoma** (60.7ºF)		Phoenix (74.4ºF)	
GWT depth (ft)		2	**7**		15	
AC Thickness (in)		1	**6**		12	
AC Stiffness (See Table 2.6)		Low Mix	**Med Mix**		High Mix	
AC Air Voids (@ time of Construction For Med Mix)		4	**7**		10	
AC Effective Binder Content		8	**11**		15	
SG Modulus (psi) (Plasticity index)	3,000 (45)	8,000 (30)	**15,000 (15)**		30,000 (0)	

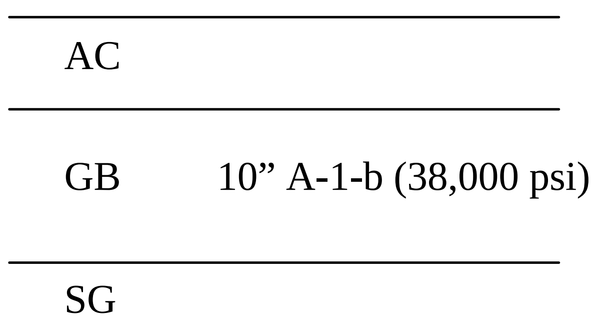

Figure 2.1 Pavement Structure

Table 2.2 Traffic Parameters used in the Study

Number of lanes in design direction	2
Percent of trucks in design direction (%)	50
Percent of trucks in design lane (%)	95
Design lane (ft)	12
Standard deviation of Traffic Wander (inch)	10

Table 2.3 AADTT Distributions by Vehicle Class

Class 4	1.8%
Class 5	24.6%
Class 6	7.6%
Class 7	0.5%
Class 8	5.0%
Class 9	31.3%
Class 10	9.8%
Class 11	0.8%
Class 12	3.3%
Class 13	15.3%

Table 2.4 Number of Axles per Truck

Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0.00	0.00
Class 5	2.00	0.00	0.00	0.00
Class 6	1.02	0.99	0.00	0.00
Class 7	1.00	0.26	0.83	0.00
Class 8	2.38	0.67	0.00	0.00
Class 9	1.13	1.93	0.00	0.00
Class 10	1.19	1.09	0.89	0.00
Class 11	4.29	0.26	0.06	0.00
Class 12	3.52	1.14	0.06	0.00
Class 13	2.15	2.13	0.35	0.00

Table 2.5 Axle Configurations

Average axle width (edge-to-edge) outside dimensions, ft)	8.5
Dual tire spacing (in)	12
Single Tire (psi)	120
Dual Tire (psi)	120
Axle Spacing - Tandem axle (in)	51.6
Axle Spacing - Tridem axle (in)	49.2
Axle Spacing - Quad axle (in)	49.2

2.5 Depth to Ground Water Table / Bedrock

For the majority of problems conducted, the ground water table depth (GWT) was set at the Medium level (7 ft), shown in Table 2.1. For the special case, where the effect of the GWT was analyzed for the sensitivity study parameter, it was varied as shown in Table 2.1 to have values of: 2 ft, 7 ft and 15 ft. The presence of a bedrock (stiff) layer was not considered as a variable in any of the studies, except for 3.15 and 3.16, which evaluated the influence of bedrock layers (1 to 20 ft) upon fatigue cracking.

2.6 Material Characterizations

2.6.1 Asphalt Concrete Mixtures

Three different asphalt concrete mixtures were used in this study. The range of E* master curves (mix stiffnesses) selected was based upon using as broad a range in stiffness of historic AC mixtures as possible. Table 2.6 shows the typical mixture properties as well as typical binder grade and properties. The mixture E* master curves chosen are representative of mixtures utilizing PG 46-34; PG 58-28 and PG 76-16 binders.

Figure 2.2 shows the master curve for the three mixtures. These plots are typically defined, in mathematical models, by use of a sigmoidal function. Table 2.7 shows the dynamic modulus equation parameters (sigmoidal function) for the three AC mixtures utilized in the sensitivity study. The intermediate mixture was selected as the base mixture for the studies in which the air voids and the effective binder content were changed when to study the effect of these two parameters on the AC fatigue cracking.

The regression models for predicting the creep compliance and tensile strengths for use in this study are based upon the Level 3 thermal fracture analysis. Table 2.8 summarizes the creep compliance values at different loading time and the tensile strength calculated for the three different asphalt concrete mixtures.

2.6.2 Unbound Layers Material

The unbound granular base properties were the same for all computer runs used in this study. However, the material properties for the subgrade soil were changed to reflect a very broad range of support values, from "very low" (Mr=3000 psi) to "high" (Mr=30,000 psi) conditions. These input values represent the "Design Conditions" for input into the program. Table 2.9 summarizes the input properties of the granular base and the four different subgrade soils used in this study.

Table 2.6 Asphalt Mixture properties

Variable	Low Mix	Med Mix	High Mix
Air Voids (%)	7	7	8
Effective Binder content (%)	12	11	10
VFA (%)	63	61	55
% Retained ¾”	0	11.62	30
% Retained 3/8”	1.16	35.3	47
% Retained # 4	27.65	52.64	52.8
% Passing # 200	11.12	7.28	8.38
PG Grade	46-34	58-28	76-16
Binder A	11.504	11.01	10.015
Binder VTS	-3.901	-3.701	-3.315

Table 2.7 Asphalt Concrete Dynamic Modulus Parameters (Sigmoidal Model Form)

Dynamic Modulus Parameters	Low Mixture	Med Mixture	High Mixture
Delta	2.8657	2.8234	-0.6719
Alpha	3.8185	3.9435	4.1776
Beta	-0.4236	-0.7920	-1.2554
Gamma	0.313351	0.313351	0.313351
C	1.255882	1.255882	1.255882

Table 2.8 Creep Compliance and Tensile Strength for each AC Mixture.

Low Mix

Loading Time (sec)	Creep Compliance (1/psi)		
	Temp (-20 ^oC)	Temp (-10 ^oC)	Temp (0 ^oC)
1	2.928E-07	3.955E-07	5.342E-07
2	3.681E-07	5.670E-07	8.732E-07
5	4.984E-07	9.128E-07	1.672E-06
10	6.267E-07	1.309E-06	2.733E-06
20	7.880E-07	1.876E-06	4.467E-06
50	1.067E-06	3.021E-06	8.554E-06
100	1.341E-06	4.331E-06	1.398E-05
Tensile Strength (psi)		467.4	

Med Mix

Loading Time (sec)	Creep Compliance (1/psi)		
	Temp (-20 ^oC)	Temp (-10 ^oC)	Temp (0 ^oC)
1	2.981E-07	4.027E-07	5.440E-07
2	3.302E-07	4.835E-07	7.081E-07
5	3.779E-07	6.157E-07	1.003E-06
10	4.185E-07	7.393E-07	1.306E-06
20	4.634E-07	8.876E-07	1.700E-06
50	5.303E-07	1.130E-06	2.409E-06
100	5.873E-07	1.357E-06	3.136E-06
Tensile Strength (psi)		413.44	

High Mix

Loading Time (sec)	Creep Compliance (1/psi)		
	Temp (-20 ^oC)	Temp (-10 ^oC)	Temp (0 ^oC)
1	3.284E-07	4.437E-07	5.993E-07
2	3.568E-07	5.023E-07	7.069E-07
5	3.982E-07	5.917E-07	8.794E-07
10	4.326E-07	6.698E-07	1.037E-06
20	4.700E-07	7.583E-07	1.223E-06
50	5.244E-07	8.934E-07	1.522E-06
100	5.697E-07	1.011E-06	1.795E-06
Tensile Strength (psi)		392.5	

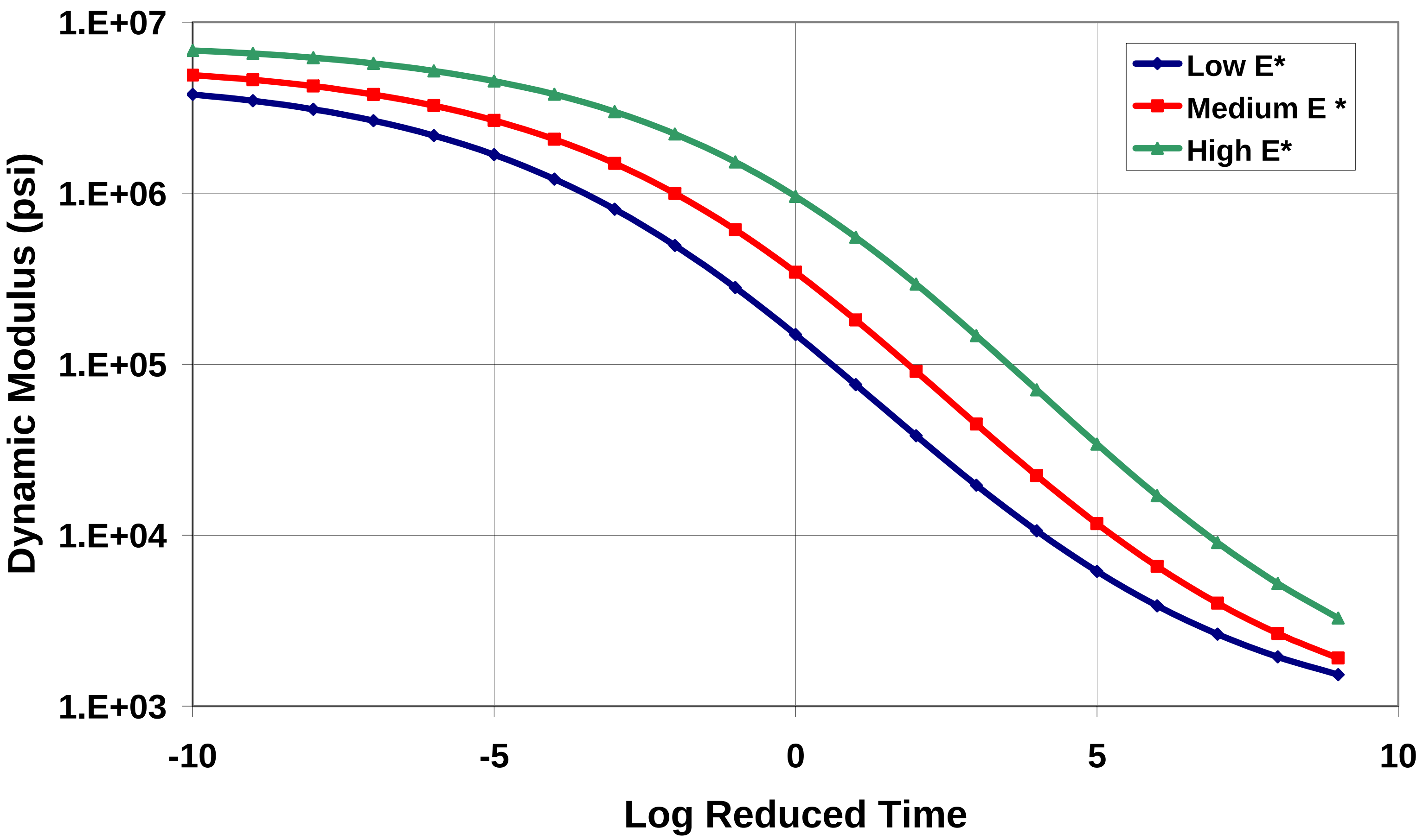

Figure 2.2 Asphalt Concrete Mixtures Master Curves

Table 2.9 Unbound Material Properties

Layer	GB	High	SG Med	SG Low	SG Very low
Classification	A–1–b	A – 3	A – 6	A–7–6	CL
Modulus (psi)	38,000	30,000	15,000	8,000	3,000
Plasticity Index – PI (%)	0	0	15	30	45
% Passing # 4	40	85	95	100	100
% Passing # 200	3	7	50	80	97
D_{60} (mm)	2	0.3	0.1	0.02	0.01

3 Sensitivity Analysis for Top-Down AC Fatigue Cracking

The following sections of this report describe the individual sensitivity studies that were conducted for the longitudinal surface (top-down) fatigue cracking analysis. The ensuing sections are presented by individual report associated with each of the individual studies noted in section 1 of this report.

3.1 Influence of AC Mix Stiffness Upon Fatigue (Longitudinal) Cracking (Thin AC Layers)

3.1.1 Objective

The objective of this section is to study the effect of changing the AC mix stiffness upon the amount of longitudinal fatigue cracking in thin AC layers.

3.1.2 Input Parameters

a. Traffic: High traffic volume (7000 AADTT)
b. Traffic Speed: 45 mph
c. Environment: Oklahoma
d. Depth to GWT: Medium (7 ft)
e. Pavement Cross Section: Three layered system as shown in Figure 2.1
f. Layer properties:
   - AC layer: 1 inch
   - AC Mix Stiffness: Low, Medium and High as shown in Table 2.6 and Figure 2.2
   - Granular Base layer: As shown in Table 2.9 and Figure 2.1
   - Subgrade: Four different subgrade support values used (Mr=30,000; 15,000; 8,000 and 3,000 psi) as shown in Table 2.9
g. Depth to bedrock: No Bedrock present

3.1.3 Results

Figures 3.1-1 shows the longitudinal cracking after 10 years of loading for three levels of AC layer stiffness and four different levels of subgrade modulus. It is very important to recognize that these results are representative for only a very thin (1 inch thick) layer of asphaltic mix.

3.1.4 Discussion of Results

The results shown in the figure are very important. First of all, regardless of the AC modulus value (E* stiffness range); longitudinal surface cracking tends to increase with increasing subgrade support (modulus). This conclusion is exactly 180 º different than the influence of subgrade support upon alligator (bottom-up) fatigue cracking. It is an obvious conclusion that the stronger the subgrade the subgrade modulus, the greater the tensile strains will be at the pavement surface (Z=0). This will lead to a greater surface fatigue cracking effect.

Another important lesson to be drawn from this sensitivity analysis is related to the fundamental fact that, for very thin AC layers, the best AC mixture is one that exhibits a very low stiffness Master Curve. As the mixture becomes more and more stiff, the amount of longitudinal cracking, due to top-down fatigue fracture, greatly increases (almost doubled).

The results shown in the figure clearly indicate that the probability of having longitudinal surface cracking is greatly increased when thin stiff AC mixtures and stronger (stiffer) subgrade support values are encountered. This is explained by the fact that the surface tensile strains occurring at the top of the AC layer become greater for stiffer foundation supports, compared to lower (weak - low Mr subgrade supports). Hence, the larger tensile strains are more prone to have fatigue fracture originate at the surface with the stronger subgrade support conditions.

3.1.5 Summary and Conclusions

For very thin AC layers, the design engineer should use as low an AC mixture stiffness as possible to eliminate and / or minimize fatigue cracking. A higher probability of top down cracking appears to exist when pavements are constructed over stiff subgrade materials. If the subgrade has a weak support condition, it is highly likely that alligator fatigue cracking will be observed. Finally, it is very important to understand that the conclusions and inferences made are very much a function of the thickness of the AC layer used in the pavement design.

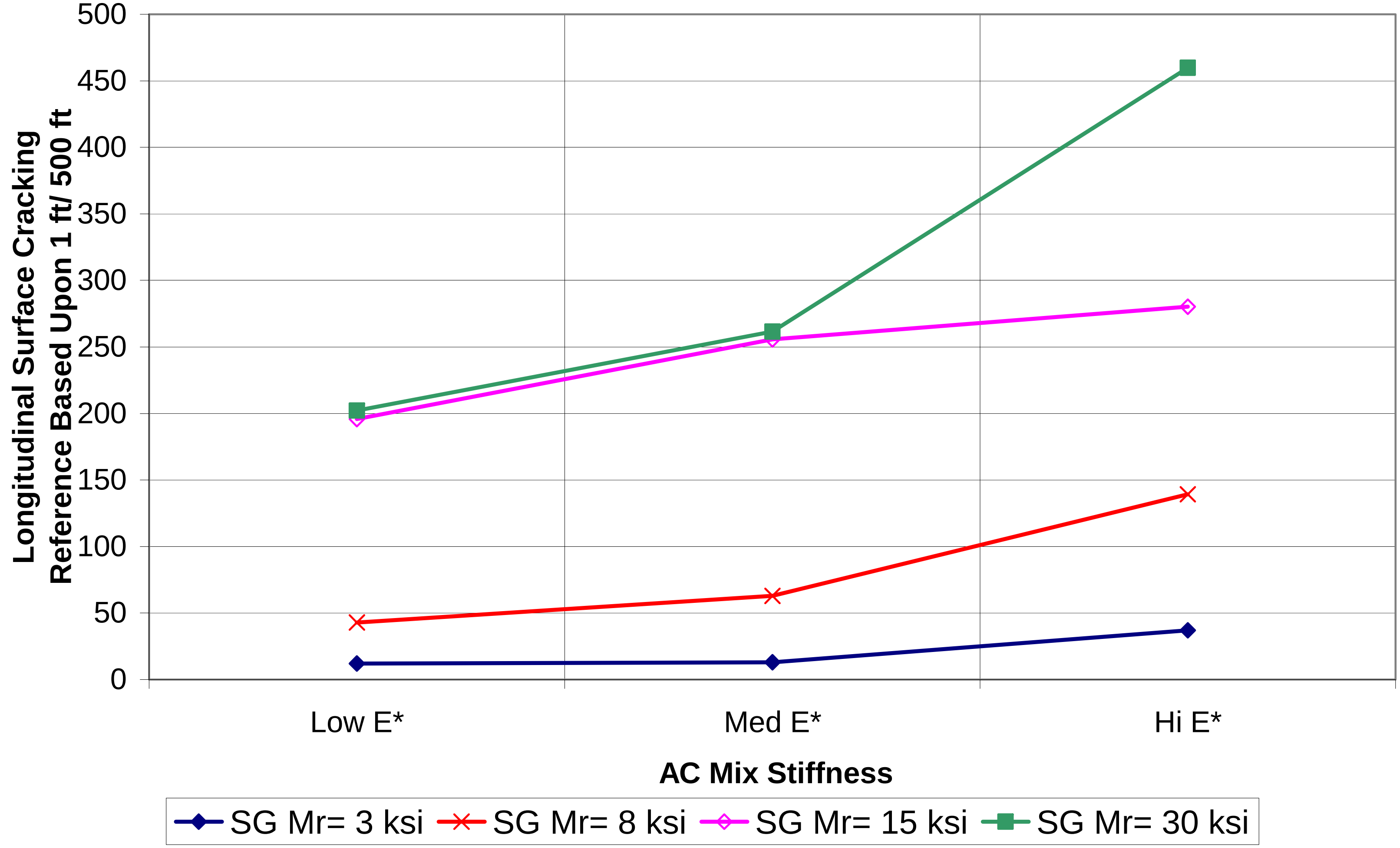

Figure 3.1-1 Effect of AC Mix Stiffness on Longitudinal Cracking, (H_{ac} = 1 in)

3.2 Influence of AC Mix Stiffness Upon Fatigue (Longitudinal) Cracking (Thick AC Layers)

3.2.1 Objective

The objective of this section is to study the effect of changing the AC mix stiffnesses on the amount of longitudinal fatigue cracking for thick AC layers.

3.2.2 Input Parameters

a. Traffic: High traffic volume (7000 AADTT)
b. Traffic Speed: 45 mph
c. Environment: Oklahoma
d. Depth to GWT: Medium (7 ft)
e. Pavement Cross Section: Three layered system as shown in Figure 2.1
f. Layer properties:
    - AC layer: 8 inch
    - AC Mix Stiffness: Low, Medium and High as shown in Table 2.6 and Figure 2.2
    - Granular Base layer: As shown in Table 2.9 and Figure 2.1
    - Subgrade: Four different subgrade support values used (Mr=30,000; 15,000; 8,000 and 3,000 psi) as shown in Table 2.9
g. Depth to bedrock: No Bedrock present

3.2.3 Results

Figures 3.2-1 shows the longitudinal fatigue cracking after 10 years of loading for three levels of AC layer stiffness.

3.2.4 Discussion of Results

One of the more critical results shown in the figure relates to the fact that longitudinal cracking is increased as the foundation (subgrade) modulus is increased. The presence of stiffer subgrade causes a larger surface tensile strain (and hence surface fatigue damage). Secondly, the interactive importance of the AC mixture stiffness is also readily apparent. For low E* mix stiffness, longitudinal cracking is greatly increased, primarily at stiff foundation (subgrade) conditions.

3.2.5 Summary and Conclusions

As the AC mix stiffness increases the amount of longitudinal surface fatigue cracking decreases. At high levels of AC mix stiffness there is almost no longitudinal surface fatigue cracking. In addition, surface cracking is increased as the subgrade (foundation) stiffness is increased.

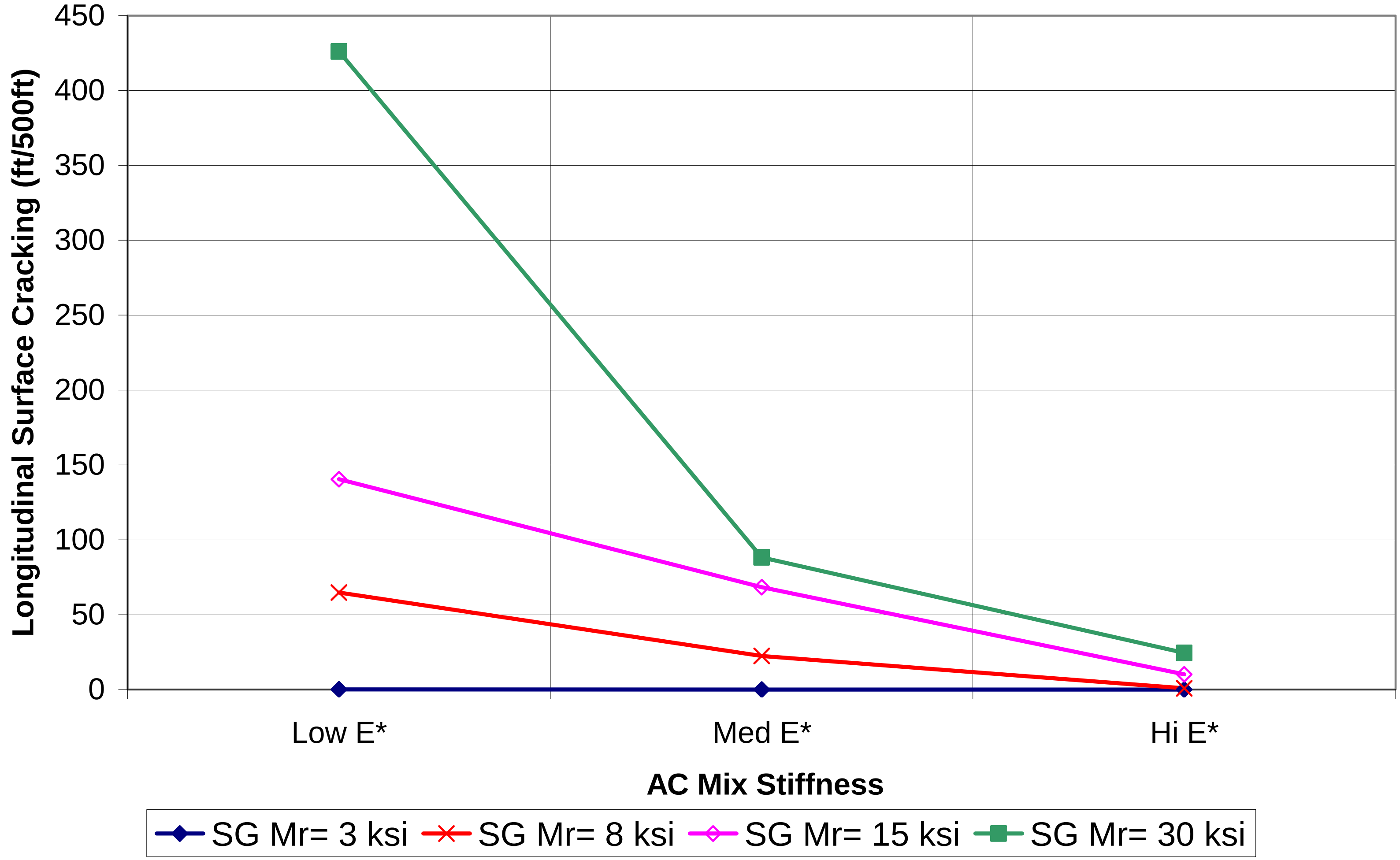

Figure3.2-1 Effect of AC Mix Stiffness on Longitudinal Cracking, (H_{ac} = 8 in)

3.3 Influence of AC Thickness Upon Fatigue (Longitudinal) Cracking

3.3.1 Objective

The objective of this section is to study the effect of AC layer thickness on the amount of longitudinal fatigue cracking.

3.3.2 Input Parameters

a. Traffic: High traffic volume (7000 AADTT)
b. Traffic Speed: 45 mph
c. Environment: Oklahoma
d. Depth to GWT: medium (7 ft)
e. Pavement Cross-Section: Three layered system as shown in Figure 2.1
f. Layer properties:
    - AC layer: 1, 2, 4, 6, 8, 10 and 12 inches
    - AC Mix Stiffness: Medium Stiff Mixture as shown in Table 2.6 and Figure 2.2
    - Granular Base layer: As shown in Table 2.9and Figure 2.1
    - Subgrade: Six different subgrade support values used (Mr=30,000; 15,000; 8,000 and 3,000 psi) as shown in Table 2.9
g. Depth to bedrock: No Bedrock present

3.3.3 Results

Figure 3.3-1 illustrates the influence of the longitudinal fatigue cracking after 10 years of loading, as a function of the AC layer thickness, for various levels of subgrade support.

3.3.4 Discussion of Results

The longitudinal surface fatigue cracking versus AC thickness relationship is somewhat similar to that found for alligator cracking. However, the longitudinal cracking increases as the support stiffness (subgrade modulus) increases. This is in contrast to the alligator cracking relationship. It can be observed that there is a rapid decrease in longitudinal surface fatigue cracking between the low thicknesses to medium thickness levels. However, there was very low longitudinal surface fatigue cracking for the medium and high thickness levels. The longitudinal surface cracking peaks at 6” thickness then decreases with the increase in AC thickness.

3.3.5 Summary and Conclusions

An optimum thickness of the AC layer, near a value of 6", will exhibit the greatest level of longitudinal fatigue cracking in a pavement system. In addition, longitudinal surface cracking increases as the subgrade support becomes stiffer (stronger).

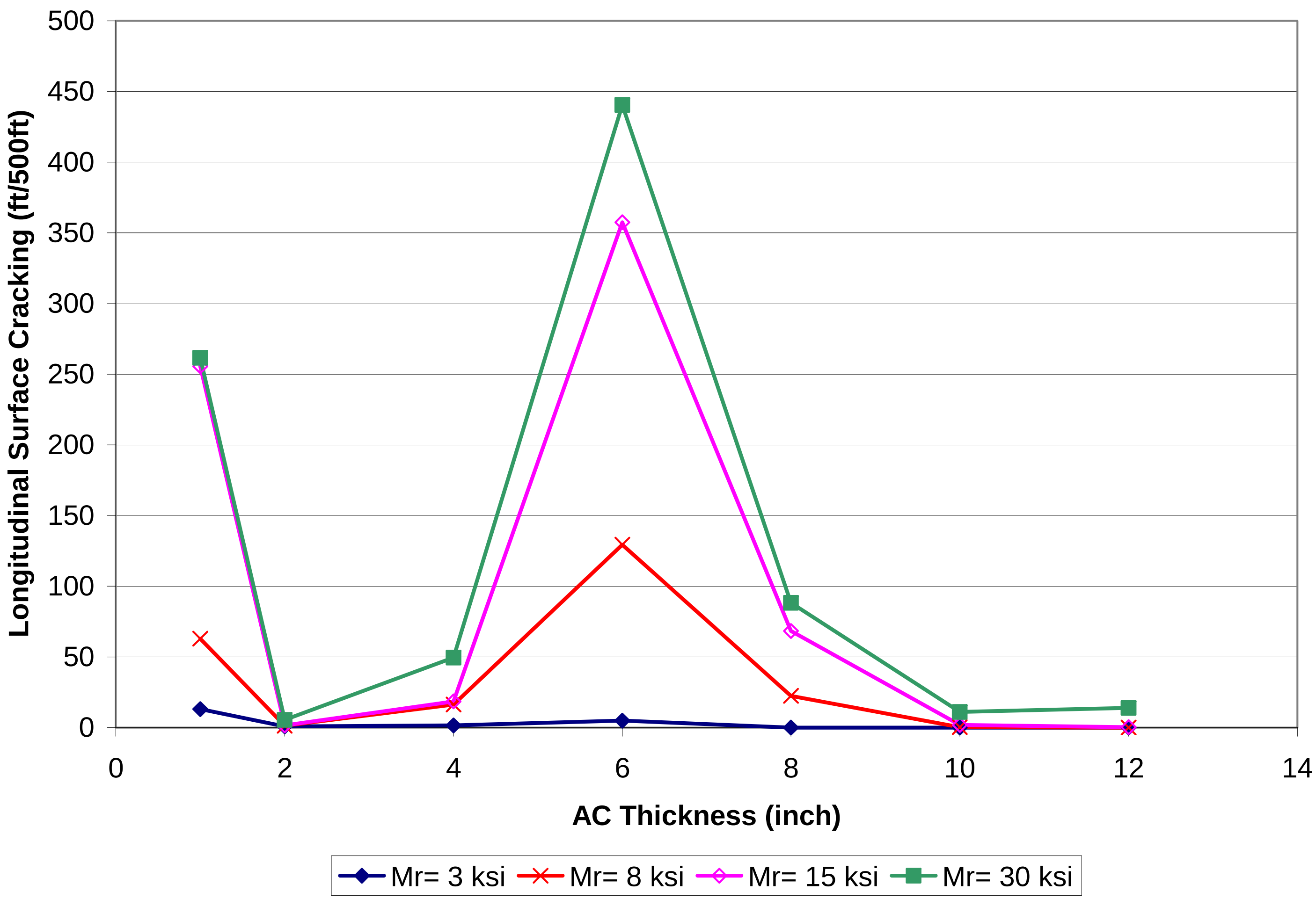

Figure 3.3-1 Effect of AC Layer Thickness on Longitudinal Fatigue Cracking

3.4 Influence of Subgrade Modulus Upon Fatigue (Longitudinal) Cracking

3.4.1 Objective

The objective of this section is to study the effect of subgrade modulus on the amount of longitudinal fatigue cracking.

3.4.2 Input Parameters

a. Traffic: High traffic volume (7000 AADTT)
b. Traffic Speed: 45 mph
c. Environment: Oklahoma
d. Depth to GWT: medium (7 ft)
e. Pavement Cross-Section: Three layered system as shown in Figure 2.1
f. Layer properties:
    - AC layer: 6 inches
    - AC Mix Stiffness: Medium Stiff Mixture as shown in Table 2.6 and Figure 2.2
    - Granular Base layer: As shown in Table 2.9 and Figure 2.1
    - Subgrade: Four different subgrade support values used (Mr=30,000; 15,000; 8,000 and 3,000 psi) as shown in Table 2.9
g. Depth to bedrock: No Bedrock present

3.4.3 Results

Figure 3.4-1 shows the longitudinal fatigue cracking after 10 years of loading for the four levels of subgrade modulus used in the sensitivity study.

3.4.4 Discussion of Results

The figure clearly illustrates the fundamental fact that the stronger the foundation (subgrade) support of the pavement system becomes; the greater the amount of longitudinal fatigue cracking that will occur. This is a direct result of the fact that larger surface tensile strains will occur when the foundation layer increases in modulus. The relative sensitivity of the rate of longitudinal cracking, due to variable subgrade support, is a function of many other design variables, such as: traffic, site climatic condition and thickness of the AC layer used in the cross section.

3.4.5 Summary and Conclusions

Increasing the subgrade support modulus will result in a increased level of longitudinal fatigue cracking in any pavement system. The sensitivity of subgrade support to the magnitude of longitudinal cracking is also a function of many other design input parameters as well.

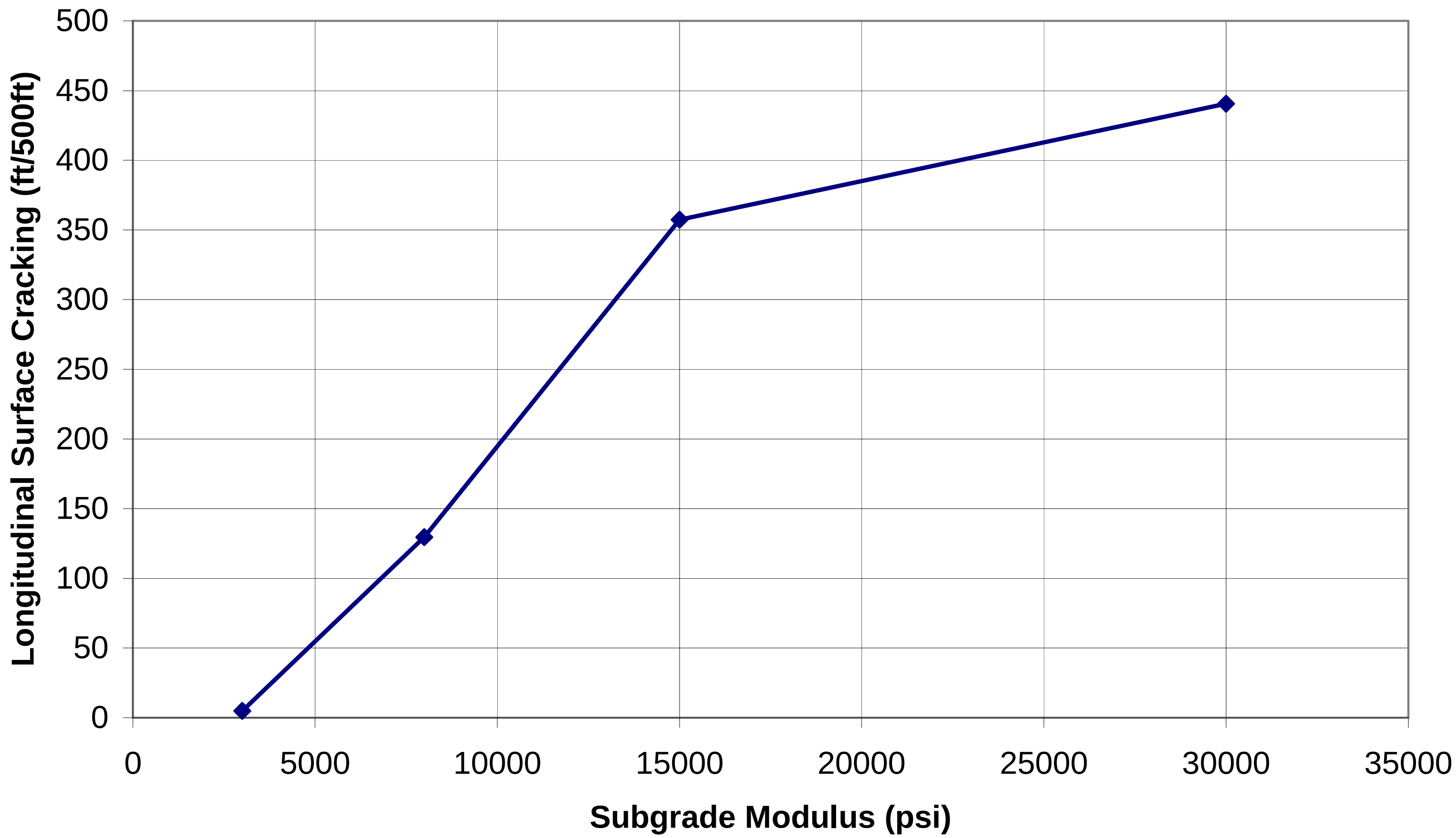

Figure3.4-1 Effect of Subgrade Modulus on Longitudinal Cracking

3.5 Influence of AC Mix Air Voids Upon Fatigue (Longitudinal) Cracking

3.5.1 Objective

The objective of this section is to study the effect of the in-situ AC air voids on longitudinal fatigue cracking.

3.5.2 Input Parameters

a. Traffic: Medium traffic volume (7000 AADTT)
b. Traffic Speed: 45 mph
c. Environment: Oklahoma
d. Depth to GWT: medium (7 ft)
e. Pavement Cross-Section: Three layered system as shown in Figure 2.1
f. Layer properties:
    - AC layer: 6 inches
    - AC Mix Stiffness: Medium Stiff Mixture as shown in Table 2.6 and Figure 2.2
    - AC Mix Air Voids: 4, 7, and 10%
    - Granular Base layer: As shown in Table 2.9 and Figure 2.1
    - Subgrade: Medium Support (Mr=15,000 psi) as shown in Table 2.9
g. Depth to bedrock: No Bedrock present

3.5.3 Results

Figure 3.5-1 shows the longitudinal fatigue cracking after 10 years of loading for the three levels of AC mix air voids used in the sensitivity study. The range of air voids used in the study reflects a very real range under typical construction conditions (4% to 10%).

3.5.4 Discussion of Results

The results shown in the figure clearly reflect the critical importance of air voids upon fatigue cracking, regardless of whether bottom up-alligator or top-down longitudinal cracking is being considered. The greater the in-place air voids of an asphalt mixture are; the greater the degree of cracking that may be expected. This effect is directly attributable to the volumetric mix term incorporated into both the controlled strain (thin AC layers) and controlled stress (thick AC layers) fatigue equation for top-down cracking. In reality, it is the mix Voids Filled with Bitumen parameter that directly influences the fatigue cracking. As this parameter is increased, the cracking is greatly reduced. Thus, this sensitivity study is directly tied to air voids and the AC content. (Also see Study 3.6)

3.5.5 Summary and Conclusions

In summary, the air voids within an AC mixture are an important parameter to influence fatigue cracking. Increasing the amount of air voids in the AC mix may significantly increase the amount of longitudinal fatigue cracking.

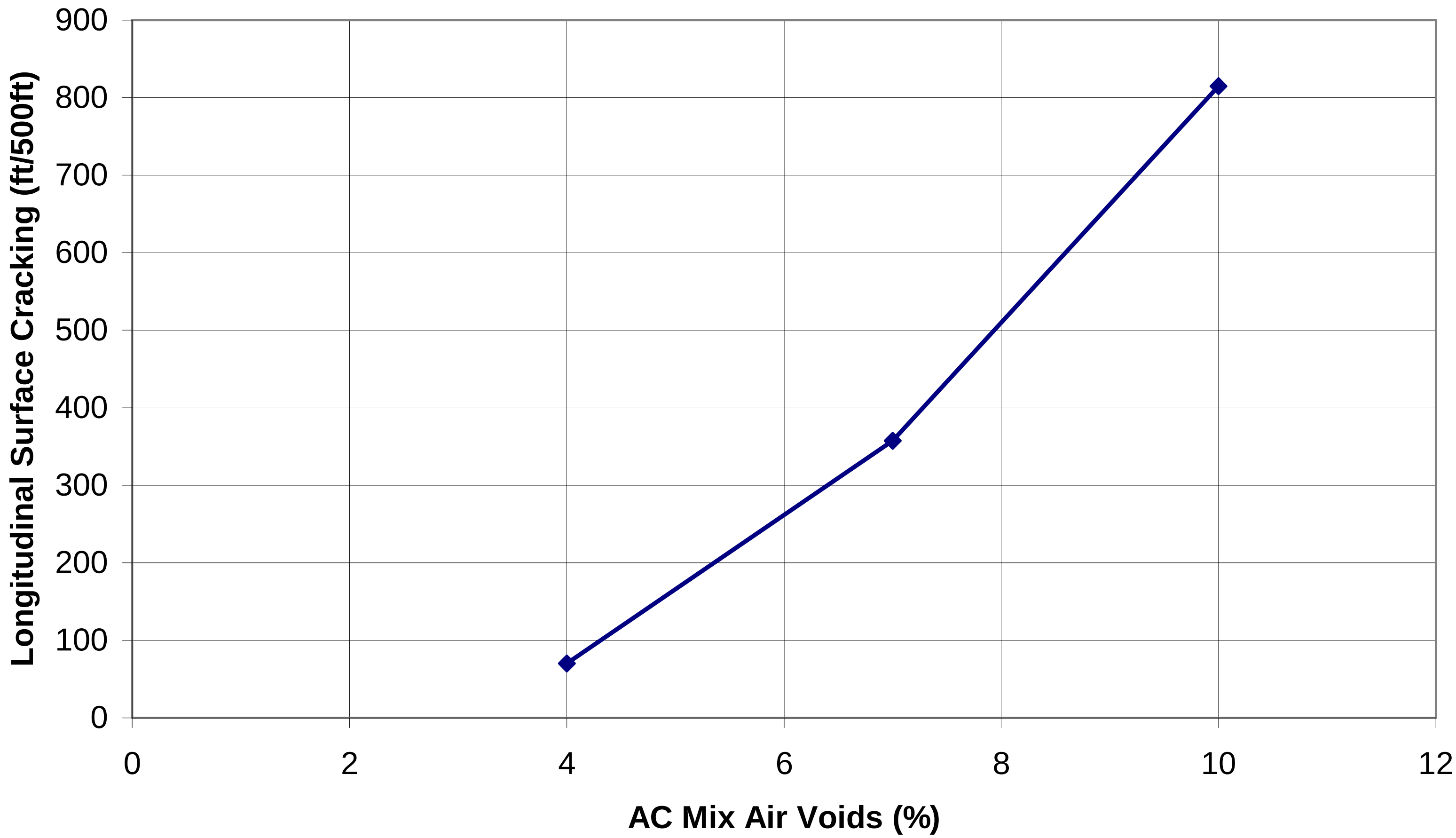

Figure 3.5-1 Effect of Percent AC Mix Air Voids on Longitudinal Fatigue Cracking

3.6 Influence of Asphalt Content (Effective Bitumen Volume) Upon Fatigue (Longitudinal) Cracking

3.6.1 Objective

The objective of this section is to study the influence of the magnitude of the effective bitumen volume present in an AC mixture upon the amount of longitudinal cracking.

3.6.2 Input Parameters

a. Traffic: Medium traffic volume (7000 AADTT)
b. Traffic Speed: 45 mph
c. Environment: Oklahoma
d. Depth to GWT: medium (7 ft)
e. Pavement Cross-Section: Three layered system as shown in Figure 2.1
f. Layer properties:
   - AC layer: 6 inches
   - AC Mix Stiffness: Medium Stiff Mixture as shown in Table 2.6 and Figure 2.2
   - AC Mix Effective Binder Content: 8, 11 and 15%
   - Granular Base layer: As shown in Table 2.9 and Figure 2.1
   - Subgrade: Medium Support (Mr=15,000 psi) as shown in Table 2.9
g. Depth to bedrock: No Bedrock present

3.6.3 Results

Figure 3.6-1 shows the longitudinal fatigue cracking after 10 years of loading for three assumed values of effective bitumen volume (Vbe). This parameter is approximately 2.0 to 2.2 times the numerical value of the AC content, in percentage form. Thus the ranges of Vbe = 8, 11 and 15 %, translate into approximate AC % values of 4%, 5+% and 7+%.

3.6.4 Discussion of Results

Like the previous study presented on the influence of mixture air voids, the influence of the amount of asphalt present in a mix also has a significant influence upon the amount of longitudinal cracking that may occur. It is observed from the figure that there is a decrease in the amount of longitudinal fatigue cracking as the amount of the effective binder volume increases. This is a direct consequence of the V_{fb} term used in the Fatigue Damage equation. As the asphalt content (effective bitumen content) is increased; the Voids filled with bitumen are also increased. This results in a greater resistance of the mixture to fracture under fatigue damage.

3.6.5 Summary and Conclusions

In summary, the amount of asphalt binder present in a mixture will directly influence the amount of fatigue cracking that will occur in the field. When the effective bitumen volume (amount of asphalt) is increased in a mix; the amount of longitudinal cracking will be decreased.

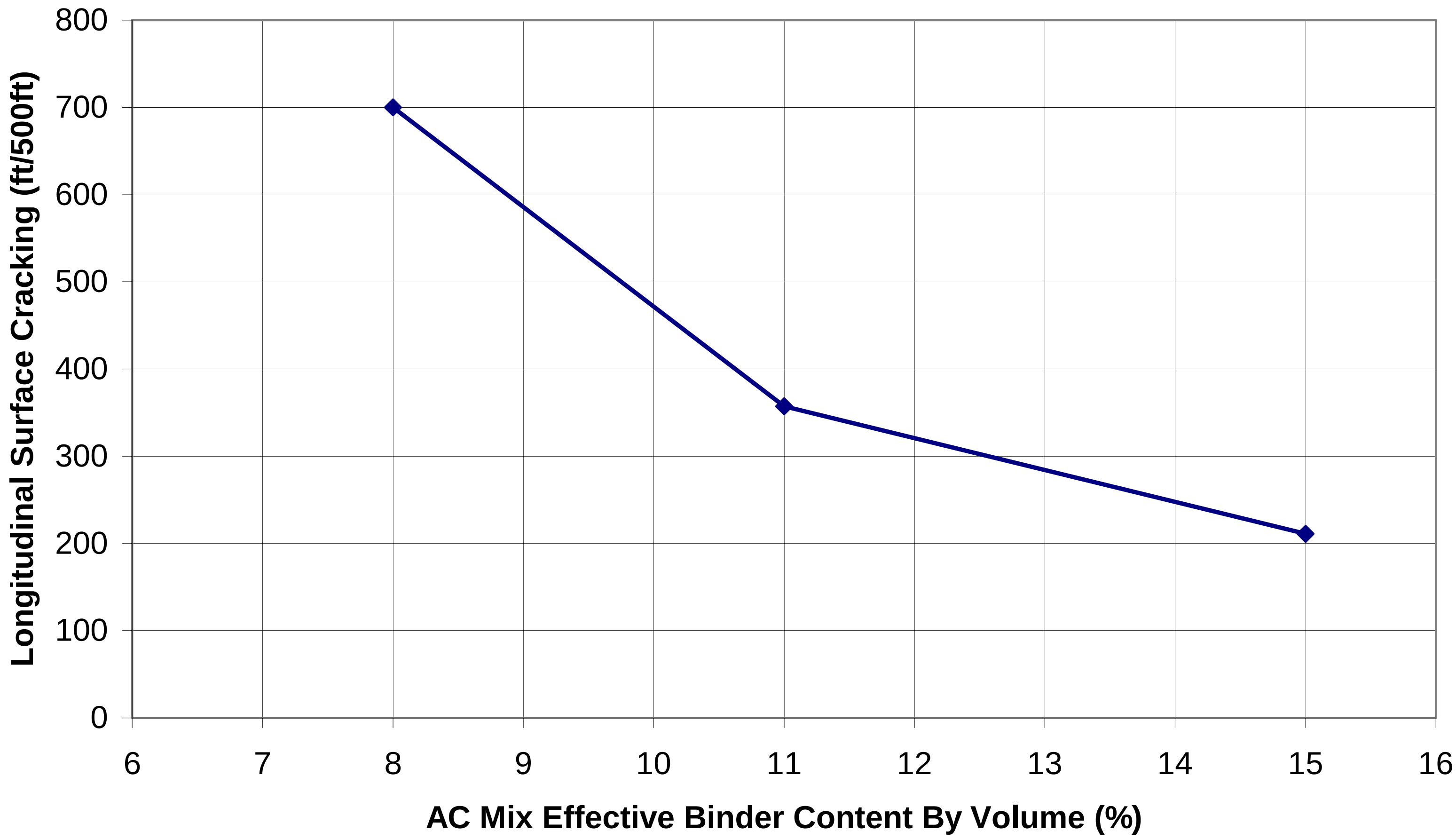

Figure 3.6-1 Effect of Percent AC Binder by volume on Longitudinal Fatigue Cracking

3.7 Influence of Depth to GWT on Fatigue (Longitudinal) Cracking

3.7.1 Objective

The objective of this section is to study the effect of depth to GWT on the amount of longitudinal cracking.

3.7.2 Input Parameters

a. Traffic: High traffic volume (1000 AADTT)
b. Traffic Speed: 45 mph
c. Environment: Phoenix
d. Depth to GWT: 2, 4, 7 and 15 ft
e. Pavement Cross-Section: Three layered system as shown in Figure 2.1
f. Layer properties:
    - AC layer: 6 inches
    - AC Mix Stiffness: High Stiff Mixture as shown in Table 2.6 and Figure 2.2
    - Granular Base layer: Constant modulus = 38,000 psi.
    - Subgrade: Five different subgrade support values used (above GWT/ below GWT) (Mr=34,000/17,600; 25,000/13075; 18,000/10260, 10,000/5,860 and 6,000/2250 psi).
g. Depth to bedrock: No Bedrock present

3.7.3 Results

Figure 3.7-1 shows the longitudinal surface fatigue cracking after 10 years of loading for four levels of depth to GWT, for low to high subgrade modulus materials.

3.7.4 Discussion of Results

As the GWT depth decreases (comes closer to the surface) the longitudinal fatigue cracking in the AC layer decreased. It can also be observed that as the subgrade modulus is increased the quantity of longitudinal cracking is also, increased. Thus, the GWT effect is clearly mirrored to the technical fact that any activity that will tent to increase the subgrade support (i.e. increasing the depth to GWT) will result in an increased level of surface longitudinal cracking. This due to the fact that as the GWT depth increases the subgrade becomes dryer and the subgrade modulus will increase, which in turn leads to a higher longitudinal cracking. The rate of at which the longitudinal cracking increases as GWT depth changes is the almost the same for all levels of the subgrade modulus. The rate of increase is higher at shallow GWT depths, and then starts to increase at a lower rate as the GWT increases. As the GWT becomes large, it would be anticipated that the influence upon fatigue damage would become insignificant.

3.7.5 Summary and Conclusions

Greater depths of the GWT will result in more longitudinal cracking due to the increased subgrade stiffness that will occur. Longitudinal cracking will almost double from a GWT depth of 2 feet to a GWT depth of 7 feet. As would be expected, longitudinal cracking will tend to increase for stiffer foundations.

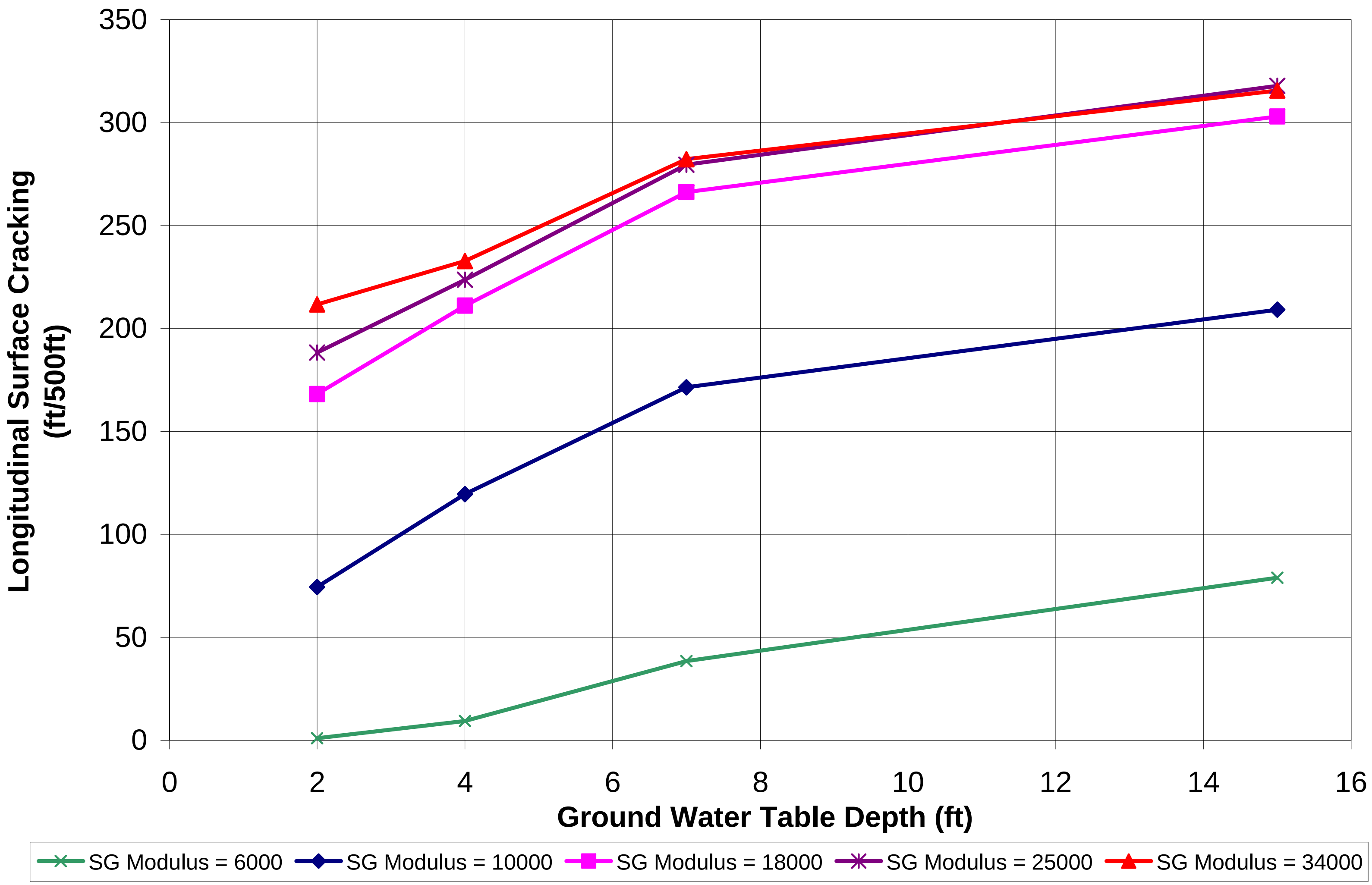

Figure 3.7-1 Effect of Depth to GWT on Longitudinal Fatigue Cracking

3.8 Influence of Truck Traffic Volume Upon Fatigue (Longitudinal) Cracking

3.8.1 Objective

The objective of this section is to investigate the influence of the truck traffic volume upon longitudinal fatigue cracking.

3.8.2 Input Parameters

a. Traffic Volume (AADTT): 100, 1000, 4000, 7000 and 50,0000
b. Traffic Speed: 45 mph
c. Environment: Oklahoma
d. Depth to GWT: Medium (7 ft)
e. Pavement Cross-Section: Three layered system as shown in Figure 2.1
f. Layer properties:
    - AC layer: 6 inches
    - AC Mix Stiffness: Medium Stiff Mixture as shown in Table 2.6 and Figure 2.2
    - Granular Base layer: As shown in Table 2.9 and Figure 2.1
    - Subgrade: Medium Support (Mr=15,000 psi) as shown in Table 2.9
g. Depth to bedrock: No Bedrock present

3.8.3 Results

Figure 3.8-1 shows the longitudinal fatigue cracking after 10 years of loading for four levels of truck traffic volume expressed in AADTT (Average Annual Daily truck Traffic). These levels of truck volumes approximately equate to: 200,000; 2,000,000; 8,000,000; 15,000,000; and 100,000,000 ESALs respectively.

3.8.4 Discussion of Results

As one would intuitively surmise, the magnitude of the truck volume plays a very significant role upon the amount of longitudinal cracking that occurs for the pavement system having the 6" AC layer noted. As traffic volume (AADTT) increases, the amount of longitudinal fatigue cracking increases in a very significant fashion.

3.8.5 Summary and Conclusions

Increasing the truck traffic volume (AADTT) increases the amount of longitudinal fatigue cracking. In essence, the parameter of truck traffic (volume), or even ESALs is an extremely sensitive parameter to longitudinal cracking. The rate of change of longitudinal cracking with truck traffic volume is nearly linear across all ranges of truck volume. The trend becomes slightly non-linear for the very high level of truck traffic investigated in this study.

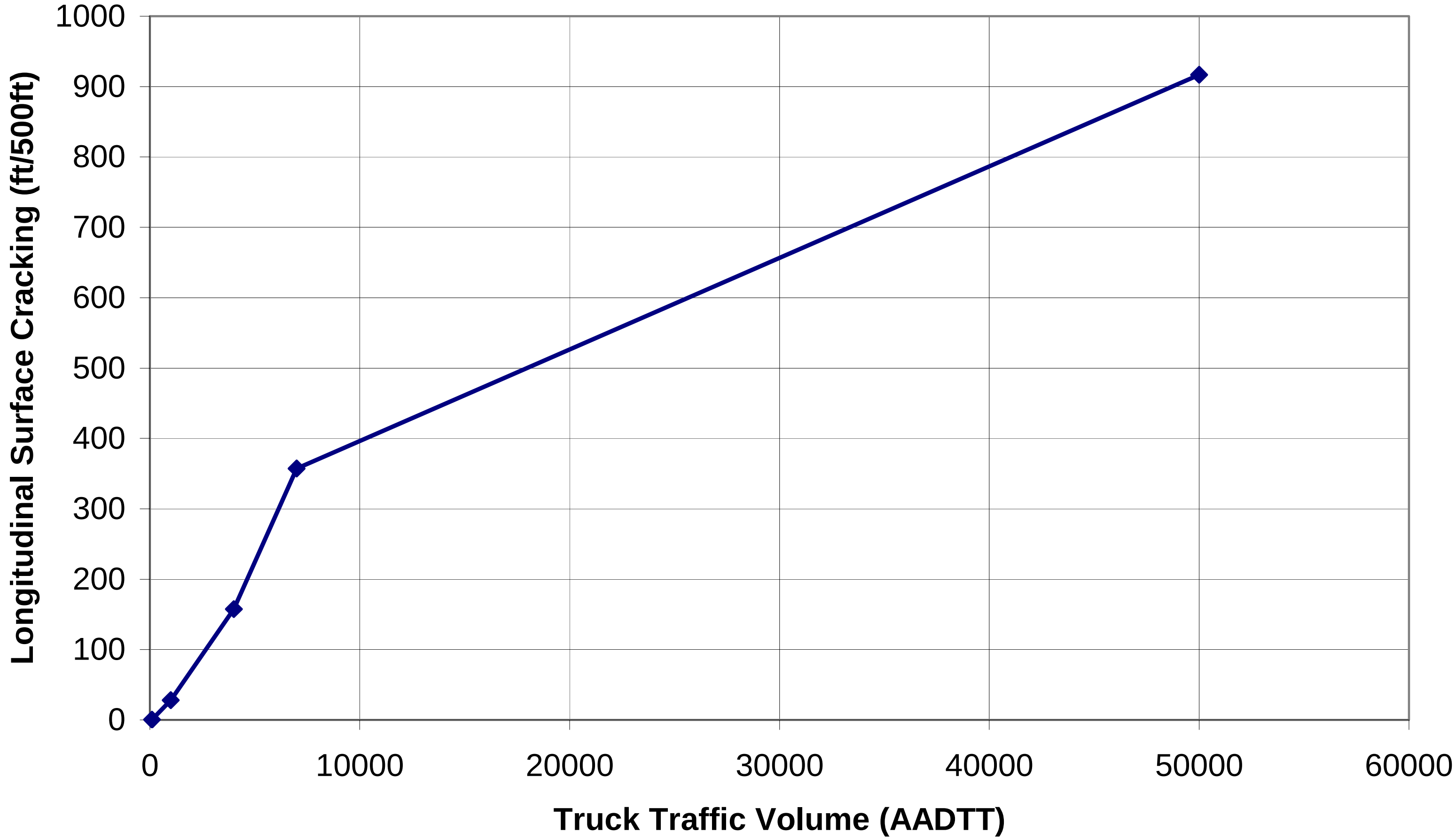

Figure 3.8-1 Effect of Truck Traffic Volume on Longitudinal Fatigue Cracking (Hac=4 in)

3.9 Influence of Traffic Speed Upon Fatigue (Longitudinal) Cracking

3.9.1 Objective

The objective of this section is to study the effect of traffic speed on longitudinal fatigue cracking.

3.9.2 Input Parameters

a. Traffic: High traffic volume (7000 AADTT)
b. Traffic Speed: 2, 25, 45 and 60 mph
c. Environment: Minnesota
d. Depth to GWT: Medium (7 ft)
e. Pavement Cross-Section: Three layered system as shown in Figure 2.1
f. Layer properties:
   - AC layer: 1 and 8 inches
   - AC Mix Stiffness: Medium Stiff Mixture as shown in Table 2.6 and Figure 2.2
   - Granular Base layer: As shown in Table 2.9 and Figure 2.1
   - Subgrade: Mr=15,000 psi used as shown in Table 2.9
g. Depth to bedrock: No Bedrock present

3.9.3 Results

Figure 3.9-1(a and b) show the results of the sensitivity study relative to traffic speed upon longitudinal cracking. Figure 3.9-1a contains results of the longitudinal fatigue cracking after 10 years of loading for the four levels of traffic speed (2 mph to 60 mph). Figures 3.9-1b provide the results of the study for a different thickness level of AC: 8" for the cold temperature condition associated with a subgrade modulus of 15,000 psi and the use of a "medium" AC stiffness.

3.9.4 Discussion of Results

Hac=1" and 8"; Cold Climatic Site

Figures 3.9-1a and b reflect the results for the influence of traffic speed upon longitudinal cracking for a thin AC layer (Fig 3.9-1a) as well as a thicker 8" AC layer (Fig 3.9-1b), for a single subgrade support modulus of Mr=15,000 psi in a cold environmental site. For the 1" thin AC layer; it can be seen that increasing the traffic speed tends to increase the longitudinal cracking. This is a very logical result due to the fact that thin AC layers, anything that will cause an increase in the E* of the AC mixture, will cause an increase in the fatigue damage and cracking that is observed. Increasing the traffic speed actually results in a shorter load stress pulse (time of loading) in the AC layer. This has a tendency, at any given temperature, to increase the mix E* (refer to master curve and reduced time effect upon the E*).

As the AC layer thickness is substantially increased (Hac=8" in Fig.3.9-1b); it can be observed that the amount of longitudinal damage and cracking, decreases with increasing speed. This reverse trend from the thin 1" AC layer, is also logical, as increasing the vehicular speed causes an increase in the E*, a decrease in the tensile strain and less damage (longitudinal cracking) to the pavement system. Finally, it should be noted that the sensitivity of speed to fatigue damage is not overly significant.

3.9.5 Summary and Conclusions

As a general conclusion, changes in the vehicular operational speed on the amount of longitudinal cracking in a pavement system may not be very large. For very thin AC layer pavement systems, the amount of fatigue damage and cracking will increase as the speed of the loading system is also increased. For very thick pavements, the reverse will occur and slightly less fatigue damage may be present at higher vehicle speeds.

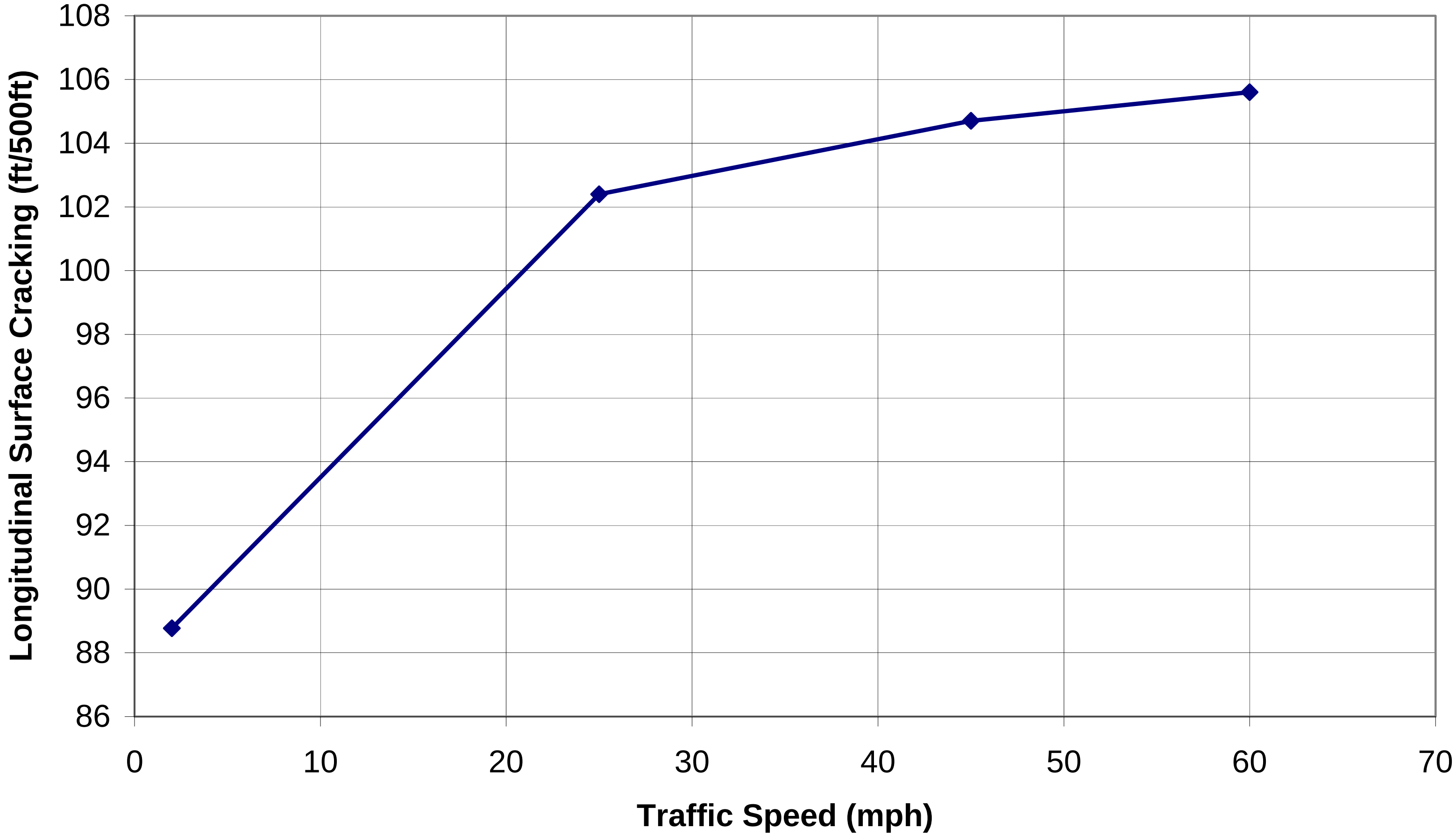

Figure 3.9-1a Effect of Traffic Speed on Longitudinal Fatigue Cracking (H_{ac} =1”, Cold Climate)

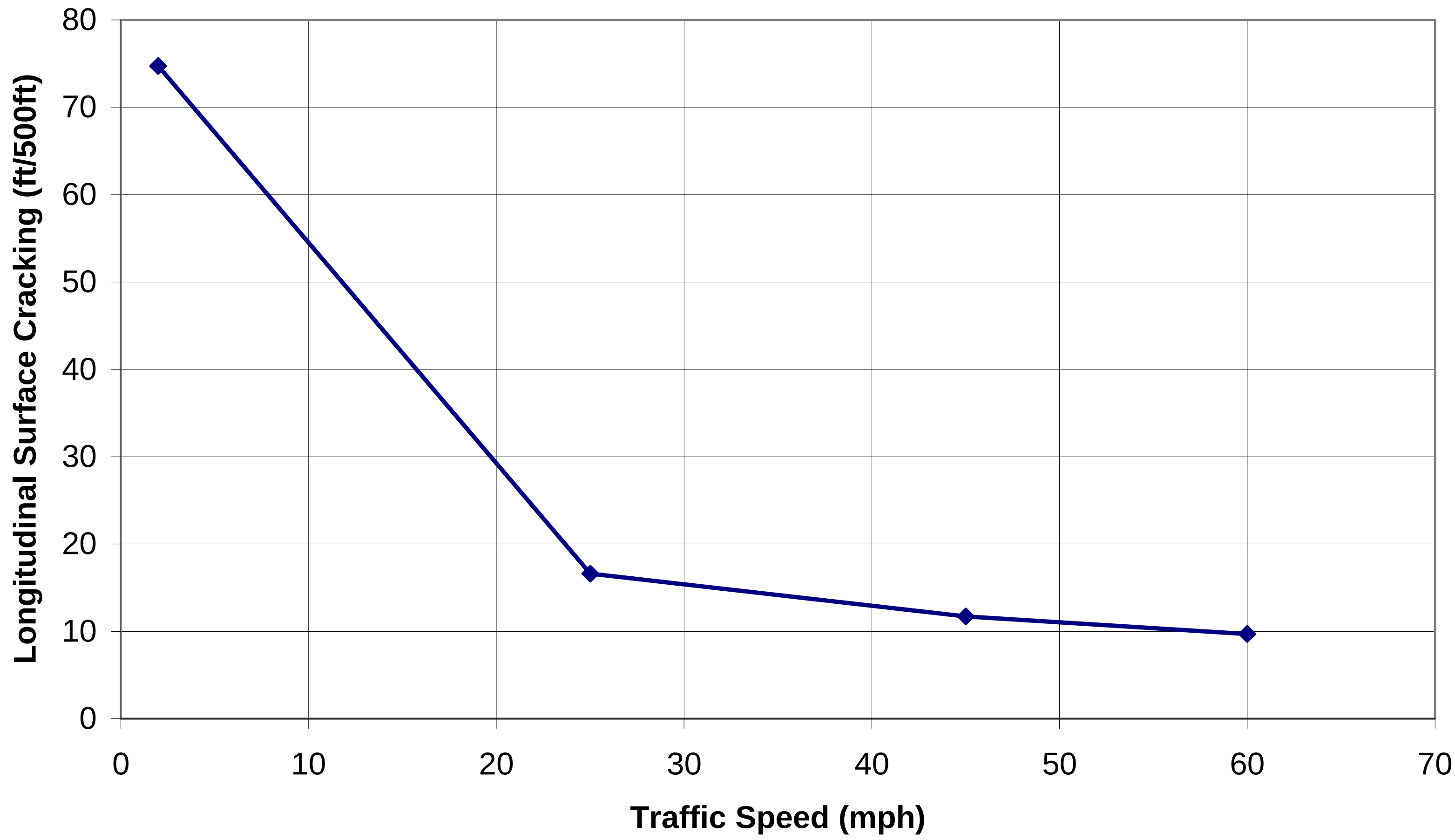

Figure 3.9-1b Effect of Traffic Speed on Longitudinal Fatigue Cracking (H_{ac} =8”, Cold Climate)

3.10 Influence of Traffic Analysis Level Upon Fatigue (Longitudinal) Cracking

3.10.1 Objective

The objective of this section is to investigate the influence of Hierarchical Traffic Level used in the analysis upon the amount of longitudinal fatigue cracking.

3.10.2 Input Parameters

a. Traffic Volume: See discussion in 3.10.3 "Results" section below
b. Traffic Speed: 45 mph
c. Environment: Oklahoma (61 deg F)
d. Depth to GWT: Medium (7 ft)
e. Pavement Cross-Section: Three layered system as shown in Figure 2.1
f. Layer properties:
   - AC layer: 6 inches
   - AC Mix Stiffness: Medium Stiff Mixture as shown in Table 2.6 and Figure 2.2
   - Granular Base layer: As shown in Table 2.9 and Figure 2.1
   - Subgrade: Medium Support (Mr=15,000 psi) as shown in Table 2.9
g. Depth to bedrock: No Bedrock present

3.10.3 Results

Figure 3.10-1 shows the impact of the Hierarchical Traffic Level selected upon the relationship of the longitudinal fatigue cracking (after 10 years of loading) for a range of traffic volumes (distributions). In this plot, five specific traffic distributions (volumes) were investigated. For the Traffic Level 1 approach, the actual traffic load axle spectrums were used as input into the program. The load spectrum approach used the input traffic assumptions noted in Tables 2.2 to 2.5. The cracking results using the Level 1 approach, for each of the five traffic volumes, is denoted as the "Load Spectra" results in the plot. For each of the five axle load spectrum distributions; the mixture axle type- load combinations were then transformed into Equivalent 18 Kip Single Axle Load repetitions (ESALs) through the use of conventional AASHTO truck damage factors, defined at a pt=2.5 and SN=5. The approximate cumulative 10-year ESAL values have been noted in Table 2.1.

3.10.4 Discussion of Results

The longitudinal fatigue cracking results shown in Figure 3.10-1 clearly indicate that the use of actual traffic load spectra, in the structural distress prediction model, results in a very significant difference in predicted cracking, compared to the use of the empirical ESAL approach to traffic that has been historically used in pavement design. For the problem investigated, the traffic axle load spectra approach (Level 1) yield more cracking compared to the use of E18KSAL's specially at higher traffic. It can be seen that the predicted difference between the two approaches tends to dramatically increase with increasing traffic. At traffic levels approaching 1 million ESALs this difference is near 30 to 50 ft/500ft; for traffic in the 10 million ESALs range, this difference is near 300 ft/500ft, while for 10^8 ESALs the predicted difference is near 700 ft/500ft.

3.10.5 Summary and Conclusions

The use of a Level 1 traffic approach, based upon the actual traffic load spectra, yields a much higher level of longitudinal cracking compared to the classical use of E18KSAL's.

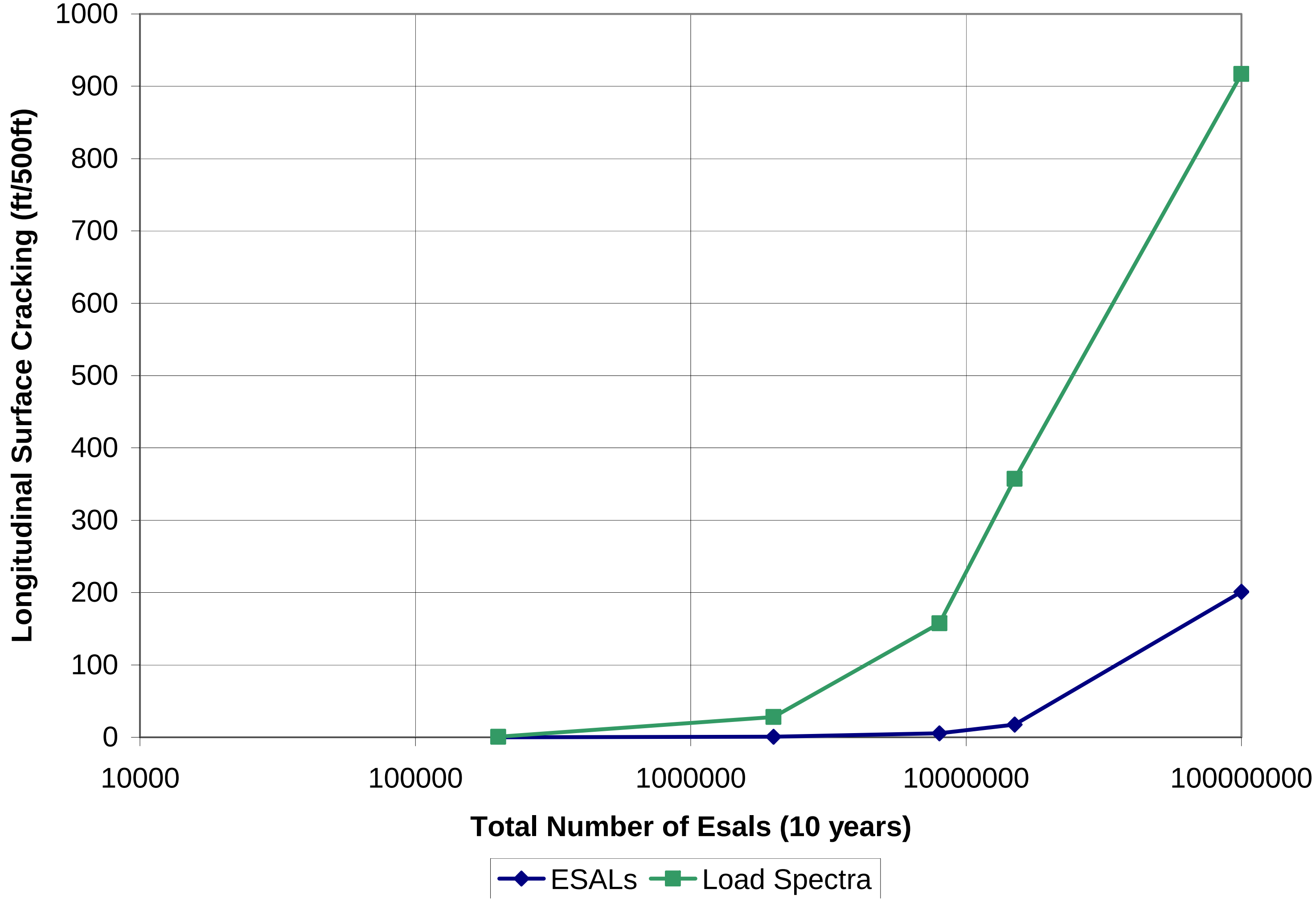

Figure 3.10-1 Effect of Traffic Analysis Level upon Longitudinal Fatigue Cracking

3.11 Influence of MAAT Upon Fatigue (Longitudinal) Cracking

3.11.1 Objective

The objective of this section is to study the effect of MAAT on the longitudinal fatigue cracking.

3.11.2 Input Parameters

a. Traffic Volume: Medium (7000 AADTT)
b. Traffic Speed: 45 mph
c. Environment: (MAAT): Minnesota (46 deg F); Oklahoma (61 deg F) and Phoenix (74 deg F)
d. Depth to GWT: Medium (7 ft)
e. Pavement Cross-Section: Three layered system as shown in Figure 2.1
f. Layer properties:
   - AC layer: 1,4, 8 and 12 inches
   - AC Mix Stiffness: High, Medium and Low Mixture Stiffnesses as shown in Table 2.6 and Figure 2.2
   - Granular Base layer: As shown in Table 2.9 and Figure 2.1
   - Subgrade: Medium Support (Mr=15,000 psi) as shown in Table 2.9
g. Depth to bedrock: No Bedrock present

3.11.3 Results

The full results of this sensitivity analysis are shown in Figures 3.11-1(a thru d). Each figure represents the relationship of predicted longitudinal cracking as a function of a specific level of AC layer thickness (Hac= 1, 4, 8 and 12"). The longitudinal fatigue cracking shown reflects 10 years of loading for the three levels of MAAT investigated.

3.11.4 Discussion of Results

The results shown are quite important relative to the selection of the appropriate level of AC mix stiffness (E*) as a function of the thickness of the AC layer. Theses results can best be interpreted for each AC thickness level presented in the analysis.

Hac=1": Referring to Figure 3.11-1a (Hac=1"); it can be observed that the amount of longitudinal fatigue cracking is always increased as the MAAT is also increased. This is true for all mixture stiffness values (E*). This result is very logical because as the MAAT increases, higher pavement temperatures will occur. This is turn, will lead to lower in-situ AC stiffnesses (dynamic moduli), which in turn will cause greater tensile strains, a lower number of repetitions to failure (Nf) and a greater degree of damage (longitudinal cracking), regardless of the original AC mix stiffness master curve (E*).

The second significant finding shown in the figure supports the discussion of study 3.1. As can be observed, the degree of longitudinal cracking that occurs is extremely sensitive to the

AC mixture stiffness (E*). For thin AC layers, the greater the mixture stiffness, the greater the degree of longitudinal cracking. In fact, for the very thin AC layer, it can be observed that there is a very strong degree of sensitivity of the AC E* stiffness to the amount of cracking that occurs.

Hac=4": The influence of increasing the AC thickness from a 1" layer to a 4" layer is illustrated in Figure 3.11-1b. It is observed that an identical conclusion, relative to the significance of the MAAT upon cracking, is noted for the 4" AC layer, compared to the 1" AC layer. The explanation of this result is the same as what was presented for the 1” AC layer. Increasing the temperature at the site will increase the tensile strains, regardless of the mixture stiffness. However, the longitudinal cracking values are much less and the change is not significant.

Hac=8": As the thickness of the AC layer is increased from 4" to 8"; the sensitivity of E* and MAAT is shown in Figure 3.11-1c. It is again obvious that the influence of warmer design sites upon an increased level of longitudinal cracking is identical to the conclusion already noted for the 1" and 4" AC layers. As previously noted, this is not surprising and the explanation provided in the previous paragraphs are applicable for any level of AC thickness.

At the Hac=8" level; it can be observed that a major change in the influence of AC mix stiffness occurs. Unlike the effect for the Hac = 1” and 4” conditions; it can be observed that at thicker HMA layers, the lower the mix stiffness; the greater the amount of longitudinal surface cracking. This conclusion is entirely opposite to what was found at the thinner AC layer thickness.

Hac=12": The influence of the MAAT and E*, upon longitudinal cracking for the thick (12") AC layer; is presented in Figure 3.11-1d. It is observed that increasing the MAAT will lead to an increase in the amount of longitudinal cracking; an identical conclusion noted for all of the three prior thickness levels. It should also be noted that the amount of cracking is greatly decreased as the AC thickness increases.

At the Hac=12" level; it can be noted that there is very little, if any, effect of the AC mixture between medium and high stiffness upon the amount of longitudinal cracking observe. However like the Hac = 8” conditions; the low stiffness had a much higher cracking.

3.11.5 Summary and Conclusions

Regardless of the thickness of the AC layer, the amount of longitudinal cracking will increase with increasing Mean Annual Air Temperature at the design site. This is true for whatever level of AC mixture stiffness is utilized in the pavement structure and thickness of the HMA layer.

However, the actual thickness of the AC layer tends to play a very critical role in defining the optimum benefit (lowest amount of longitudinal cracking damage) for the specific mix in question. As a general rule, for very thin AC layers; the use of a very stiff AC mixture will result in maximum fatigue damage and cracking. As previously noted, it appears that maximum fatigue damage will occur with HMS layer thickness near 6”. As the AC layer thickness is increased to levels of 10" - 12+", the use of stiff mixtures (high E* values) is preferable and will lead to a minimum of fatigue damage and longitudinal cracking.

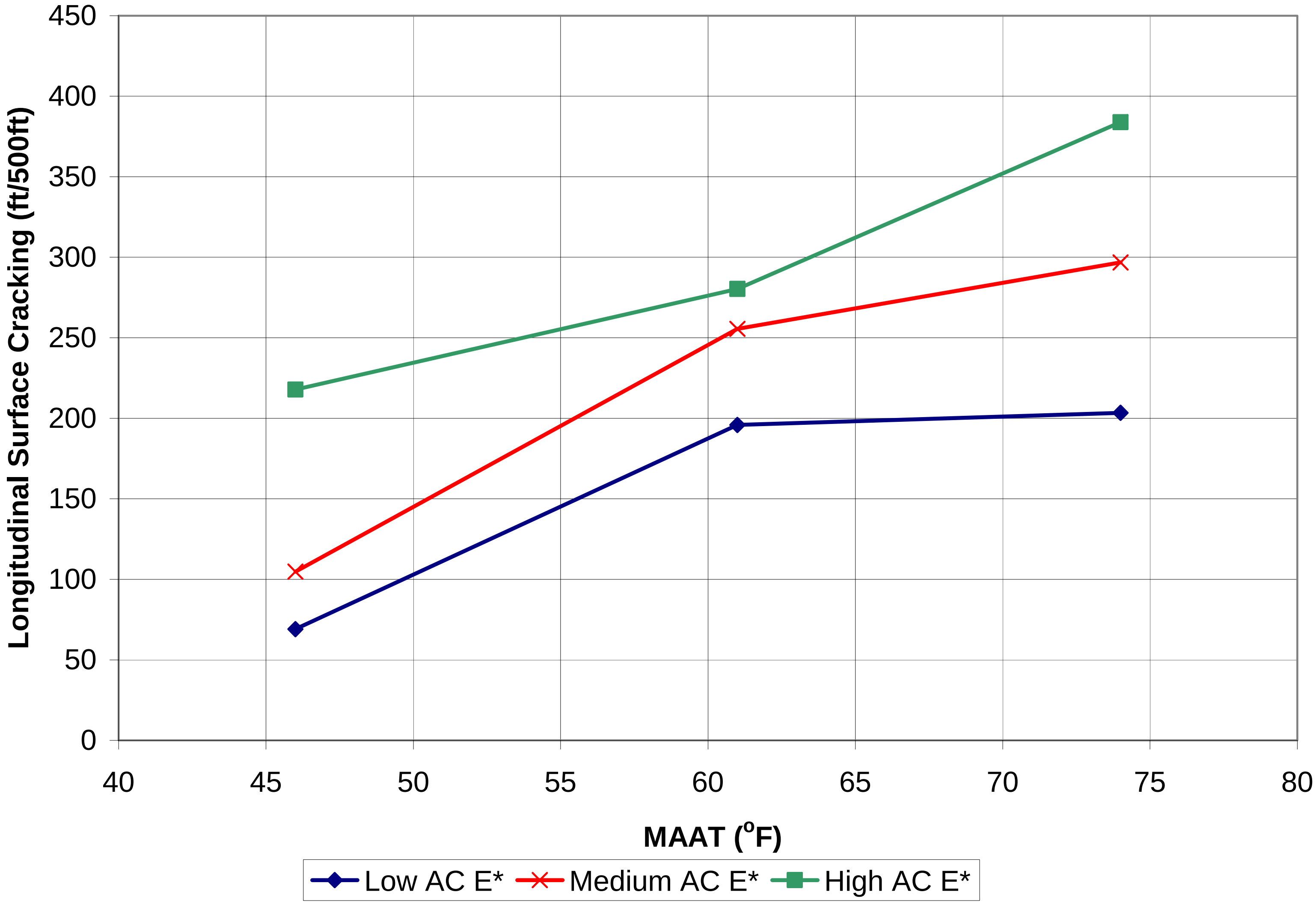

Figure 3.11-1a Effect of MAAT on Longitudinal Fatigue Cracking (H_{ac} =1”)

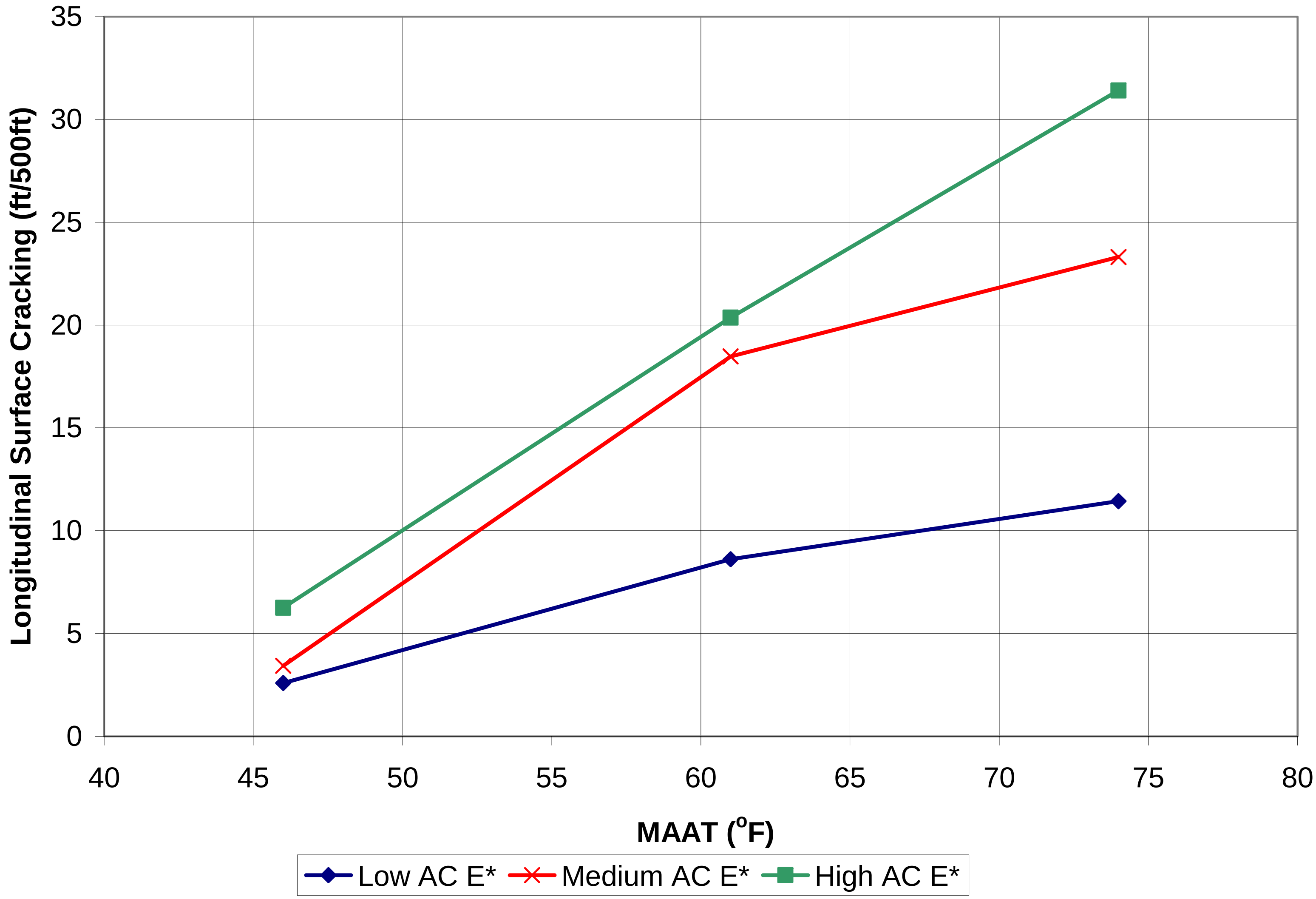

Figure 3.11-1b Effect of MAAT on Longitudinal Fatigue Cracking (H_{ac} =4”)

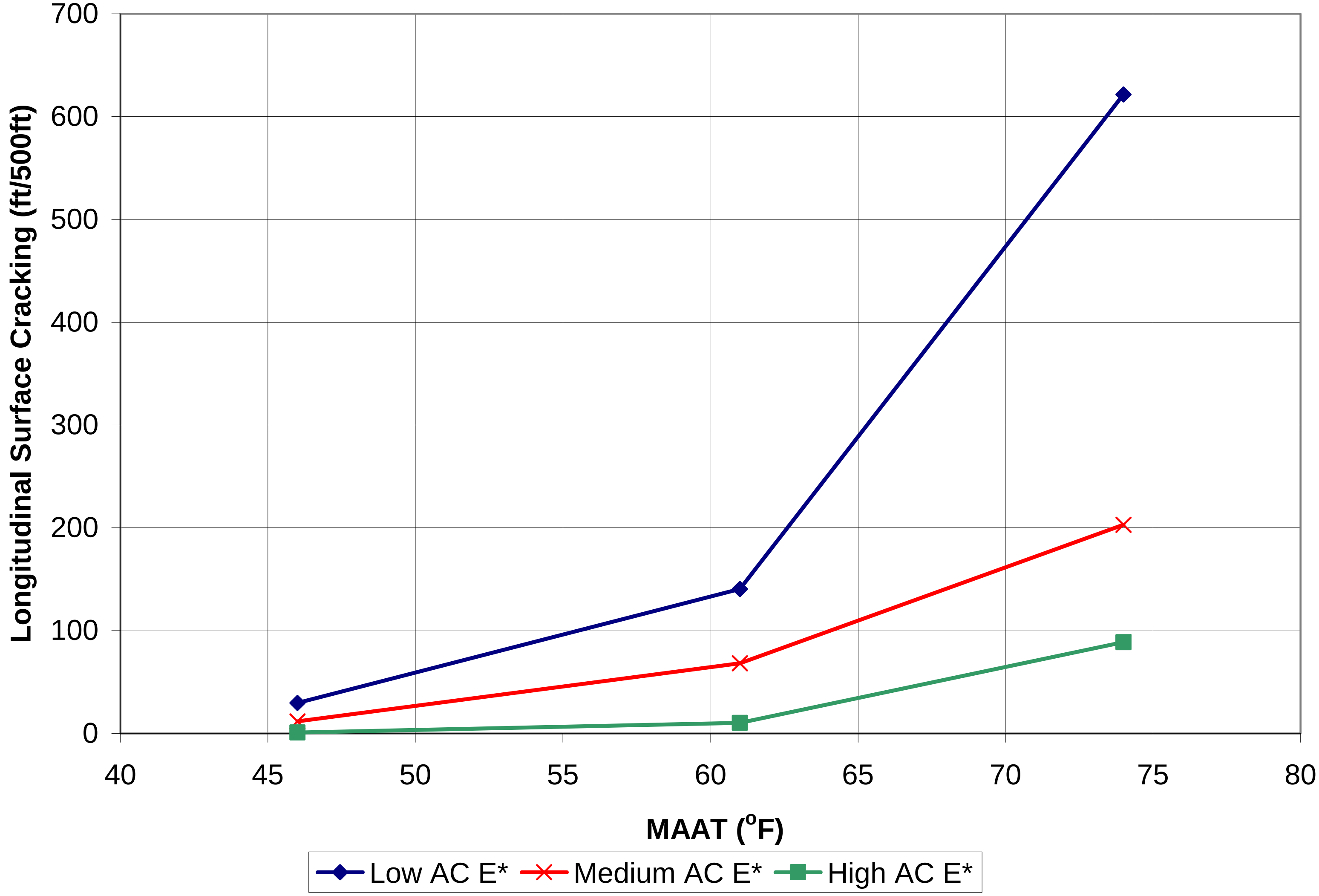

Figure 3.11-1c Effect of MAAT on Longitudinal Fatigue Cracking (H_{ac} =8”)

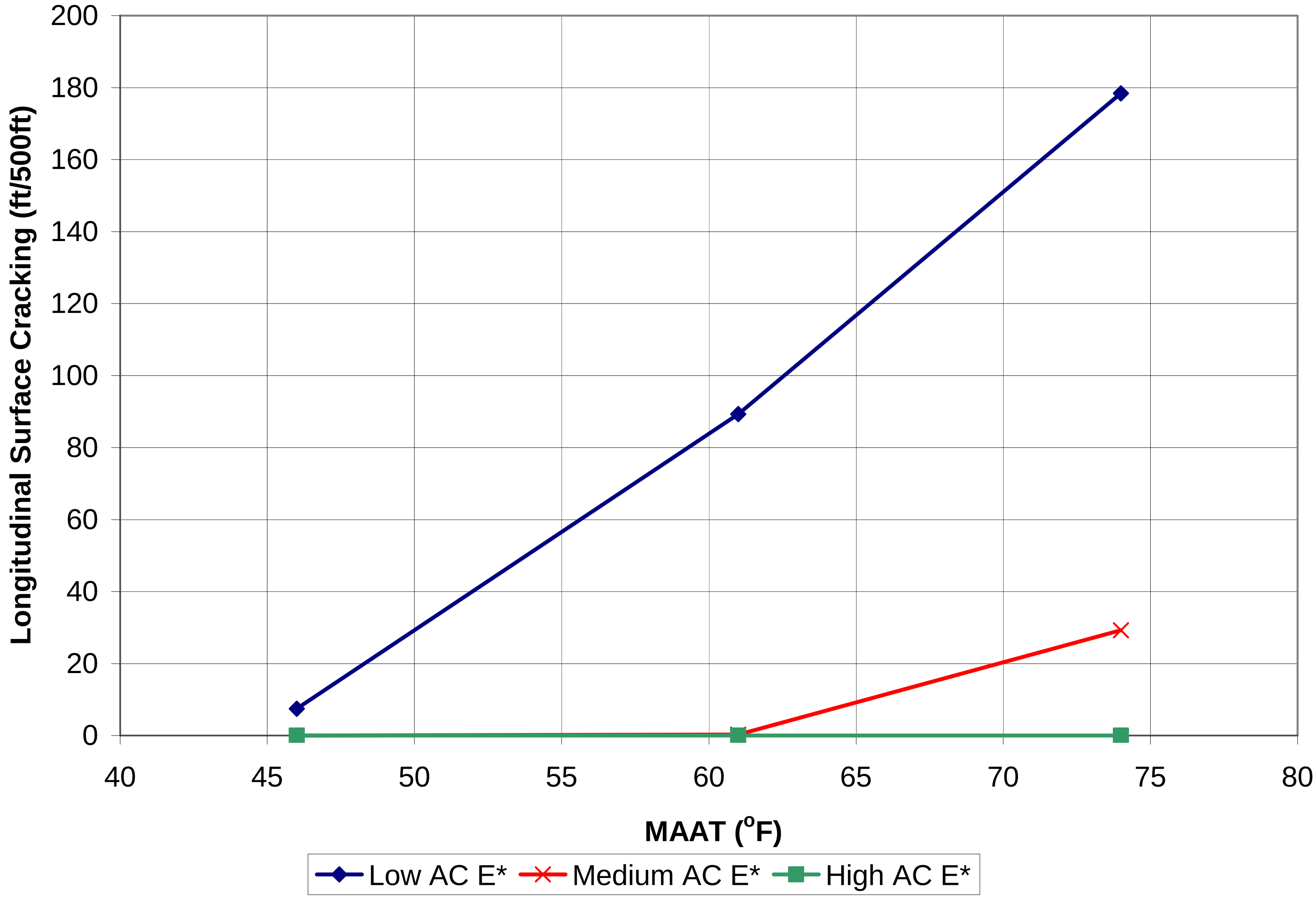

Figure 3.11-1d Effect of MAAT on Longitudinal Fatigue Cracking (H_{ac} =12”)

3.12 Influence of Bedrock Depth upon Fatigue (Longitudinal) Cracking

3.12.1 Objective

The objective of this section is to study the effect of changing the depth of bedrock under a flexible pavement upon the amount of longitudinal fatigue cracking.

3.12.2 Input Parameters

a. Traffic: High traffic volume (7000 AADTT)
b. Traffic Speed: 45 mph
c. Environment: Oklahoma
d. Depth to GWT: medium (7 ft) for bedrock depths 10 and 20 ft; GWT at top of Bedrock for all depths less than 5 ft
e. Pavement Cross-Section: Three layered system as shown in Figure 2.1
f. Layer properties:
   - AC layer: 6 inch
   - AC Mix Stiffness: Medium as shown in Table 2.6 and Figure 2.2
   - Granular Base layer: As shown in Table 2.9 and Figure 2.1
   - Subgrade: Two subgrade support values used (Mr=30,000 and 3,000 psi) as shown in Table 2.9
g. Depth to bedrock: 3', 4', 5', 6’, 7’, 12' and 20' (from top of pavement): E_{br}= 750,000 psi

3.12.3 Results

Figures 3.12-1 shows the longitudinal fatigue cracking (after 10 years of loading) as a function of the depth of the Bedrock layer, for two levels of subgrade support evaluated.

3.12.4 Discussion of Results

The figure illustrates the fact, that regardless of the subgrade support value, the presence of a bedrock layer at depths greater than 6' to 7' below the pavement surface will have very little, if any, influence upon the surface longitudinal cracking that is observed. On the other hand, if the bedrock layer comes within several feet of the subgrade surface, its presence may be directly responsible for the development of significant levels of surface cracking to be observed. This result is totally consistent with the influence of subgrade (foundation) stiffness upon longitudinal cracking previously discussed.

Again, the reason for this can be easily explained through layered response models and results. If the effective foundation support of a pavement system is very soft and there is no bedrock present, the magnitude of any surface tensile strains induced by vehicular traffic is very small. This would lead to little, if any, surface fatigue cracking to occur on the facility. However, as the "effective foundation support" is dramatically increased, (due to an increase in subgrade Mr and/or the presence of bedrock layer near the surface); a significant increase in the surface tensile strains will occur. This impact, results in a much greater probability of surface fatigue cracking to occur. For surface cracking, the presence of a stiffer subgrade, in combination with the stiff bedrock layer, will result in a more damaging surface condition than if a low support subgrade where present.

3.12.5 Summary and Conclusions

Depth of bedrock may also influence the amount of longitudinal surface cracking that may be present in a pavement system. For the example pavement evaluated, it appears that the "effective zone of influence of the bedrock layer" must be within 6' to 7' of the pavement surface to influence the amount of surface fatigue cracking that may occur.

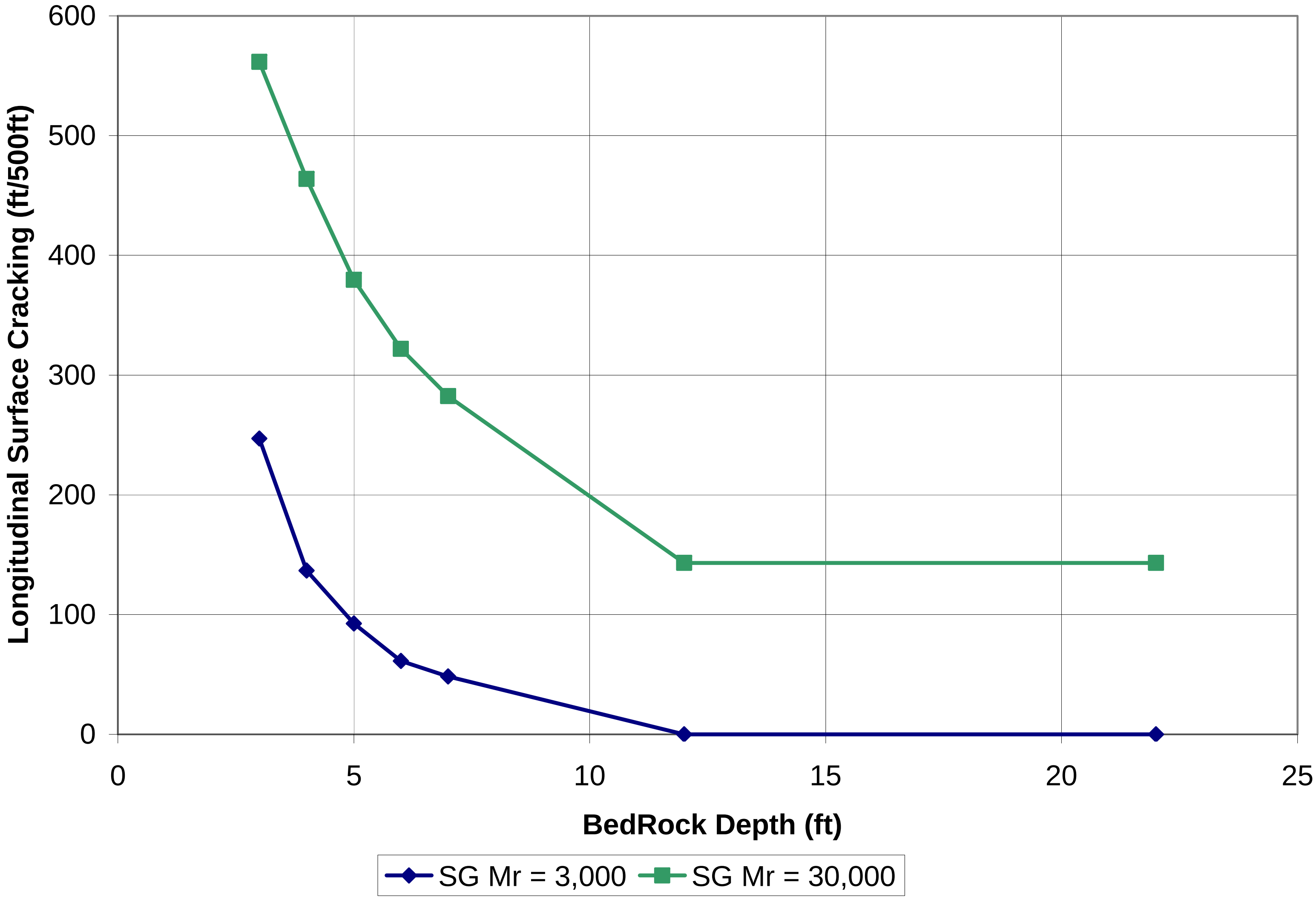

Figure 3.12-1 Effect of Bedrock Depth Upon Longitudinal Fatigue Cracking