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16. Abstract

In this project, researchers conducted an extensive sensitivity analysis of the new M-E Design Guide, development of default input files, and a review of current procedures to develop an implementation strategy and justification of the new pavement design guide.

The sensitivity analysis was conducted for the primary design modules, for each level of input data (e.g., Level 1, 2, and 3). The objective of the sensitivity analysis was to determine to what degree the input parameters affect the performance of the initial design.

In addition to the sensitivity analysis, TxDOT's current pavement design approach was reviewed and contrasted to the design guide to determine what additional tests or other changes will be needed for the implementation of the new design guide.

Initial input materials parameters and regional calibration values were developed using available materials information and pavement performance data in TxDOT and research projects.

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SENSITIVITY ANALYSIS OF AND STRATEGIC PLAN DEVELOPMENT FOR THE IMPLEMENTATION OF THE M-E DESIGN GUIDE IN TXDOT OPERATIONS

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The contents of this report reflect the views of the authors, who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation (TxDOT) or Federal Highway Administration (FHWA). This report does not constitute a standard, specification, or regulation. Additionally, this report is not intended for construction, bidding, or permit purposes. Thomas J. Freeman was the principal investigator for the project.

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CHAPTER 1 - INTRODUCTION TO THE MECHANISTIC-EMPIRICAL (M-E) DESIGN GUIDE

1.1 INTRODUCTION TO THE M-E DESIGN GUIDE

This pavement design program has been referred to by several different designations. Throughout this document, the terms M-E Design Guide, American Association of State Highway Transportation Officials (AASHTO) 2002, AASHTO Guide, and National Cooperative Highway Research Program (NCHRP) 1-37 program will be used interchangeably. Where possible, the term M-E Design Guide will be used, but some of the sources for this report use the other designations.

1.1.1 Objective of the M-E Design Guide

The overall objective of the M-E Design Guide (NCHRP 2004) is to provide the highway community with a state-of-the-practice tool for the design of new and rehabilitated pavement structures, based on mechanistic-empirical principles. This objective was accomplished through developing a design guide that is based on pavement design procedures that use existing mechanistic-empirical technologies.

The M-E Design Guide represents a major change in the way pavement design is performed. The designer first considers site conditions (traffic, climate, subgrade, existing pavement condition for rehabilitation) and construction conditions in proposing a trial design for a new pavement or rehabilitation. The trial design is evaluated for adequacy by comparing the desired maximum levels of distress to that predicted by the guide. If the design does not meet desired performance criteria, the designer revises and repeats the evaluation process as necessary. Thus, the designer is fully involved in the design process and has the flexibility to consider different design features and materials for the prevailing site conditions.

The various editions of the *AASHTO Guide for Design of Pavement Structures* (AASHTO 1972, AASHTO 1986, AASHTO 1993) and other empirical design systems have served well for several decades; nevertheless, many serious limitations exist for their continued use as the nation's primary pavement design procedures:

- Traffic Loading Deficiencies: Heavy truck traffic levels have increased tremendously (about 10 to 20 times). The existing design systems cannot be used reliably to design for this level of traffic. Thus, application of the procedure to modern traffic streams means the designer often must extrapolate the design methodology far beyond the data and experience providing the basis for the procedure.

- Rehabilitation Deficiencies: Pavement rehabilitation design procedures were not considered at the AASHO Road Test (AASHO 1962). Therefore, all rehabilitation procedures are completely empirical and very limited, especially in consideration of heavy traffic.

- Climatic Effect Deficiencies: Direct consideration of climatic effects at a project site will lead to improved pavement performance and reliability.

- Material Deficiencies: Today, there exist many different types of hot-mix asphalt concrete (HMAC) and Portland cement concrete PCC mixtures (e.g., Superpave, stone-mastic asphalt, high-strength PCC) whose effects cannot be fully considered. Various types of modified (stabilized) bases are used routinely, especially for heavier traffic loadings.

- Performance Deficiencies: Earlier AASHTO and other pavement design procedures relate the thickness of the pavement layers to serviceability. However, other failure modes (e.g., rutting, thermal cracking, faulting) may require rehabilitation for reasons that are not related directly to serviceability.

1.1.2 Benefits of a Mechanistic-Empirical Procedure

The mechanistic-empirical design procedure included in the M-E Design Guide provides the tools for evaluating the effect of variations in materials on pavement performance. The M-E Design Guide provides a rational relationship between construction and materials specification and the design of the pavement structure. Because the mechanistic procedures are able to better account for climate, aging, present day materials, and present day vehicle loadings, variation in performance, in relation to design life, should be reduced. This capability will reduce life cycle costs significantly over an entire highway network.

Additional benefits of mechanistic design procedures, already recognized in the 1986 AASHTO Guide, are:

- Estimates of the consequences of new loading conditions can be evaluated. For example, the damaging effects of increased loads, high tire pressures, multiple axles, and other factors can be modeled using mechanistic procedures.
- Better utilization of available materials can be considered. For example, the use of stabilized materials in both rigid and flexible pavements can be simulated to predict future performance.
- Improved procedures to evaluate premature distress can be developed, and it is possible to analyze why some pavements exceed their design expectations. In effect, better diagnostic techniques can be utilized.
- Aging can be included in estimates of performance (e.g., asphalt hardens with time, which, in turn, affects both fatigue cracking and rutting).
- Seasonal effects such as thaw-weakening can be included in estimates of performance.
- Consequences of base erosion under rigid pavements can be evaluated.
- Methods can be developed to better evaluate the long-term benefits of providing improved drainage in the roadway section.

An additional important benefit of the mechanistic-based approach included herein is that, unlike empirical procedures, the concepts are generally applicable and modular such that a full range of future enhancements can be developed and implemented (e.g., improved rutting model, improved damage accumulation algorithm, improved laboratory testing procedures, improved backcalculation, etc.). These improvements can be incorporated continuously over time and when a new or modified material is identified or proposed, the engineering properties can be modeled and the material evaluated using the M-E Design Guide. Therefore, the procedure will not become outmoded with changes in construction materials, traffic patterns, vehicle types, or tire types and configurations. In other words, the present Guide is the first and simplest mechanistic-empirical procedure for the years to come. Unfortunately, existing mechanistic-empirical procedures cannot yet take advantage of all these benefits.

1.1.3 Principles of a Mechanistic Procedure

From an engineering point of view, there is much to be desired about a mechanistic approach to pavement design. "Mechanistic" refers to the application of the principles of engineering mechanics, which leads to a rational design process. Some of the "empirical" part of mechanistic-empirical design relates to the characterization of materials or to traffic, environment, or other inputs to the design process. Other empirical parts of this Guide relate to field performance data used to correlate to accumulated damage. This "transfer" function, as it is sometimes called, relates the theoretical computation of "damage" (which is, in turn, a function of pavement deflection, strain, or stress responses) at some critical location with measured distress, completing the full mechanistic-empirical loop of the pavement design.

Generally, flexible and rigid pavements respond to loads in such different ways that there are fundamental differences in the analysis theories applied. Basically, for rigid pavement slabs nonlinearity of the stress-strain relationship is not an issue, but discontinuities such as cracks and joints are of major importance. Essentially, the opposite is true with flexible pavements—nonlinearity of the stress-strain relationship is a major issue while the importance of discontinuities are secondary or non-existent. Rehabilitated pavements, especially those with a combination of rigid and flexible layers, are an entirely different class of pavements and analysis.

While the mechanistic approach to pavement design and analysis is much more rational than the strictly empirical approach, it is also much more technically demanding. As mentioned earlier, mechanistic-empirical procedures were not practical until the advent of high-speed computers because of the computational demands associated with the differential equations and finite element (FE) matrix solutions employed by the various analysis models. The current version of the M-E Design Guide is based on the simplest models, i.e., linear multilayer theory. The next generation will probably include FE and nonlinear analyses.

1.1.4 Design Approach

1.1.4.1 General Approach

This M-E Design Guide represents a major change in the way design is performed. In reality, the Guide is an analysis tool that can be used in the design by proposing a trial design for a new pavement or rehabilitation, analyzing the thickness design and proposed materials, and varying all these inputs until all design criteria are met. The design/analysis process for new and rehabilitated pavement structures includes consideration of the following:

- foundation/subgrade,
- existing pavement condition,
- paving materials,
- construction factors,
- environmental factors (temperature and moisture),
- traffic loadings,
- subdrainage,
- shoulder design,
- rehabilitation treatments and strategies,
- new pavement and rehabilitation options,
- pavement performance (key distresses and smoothness),
- design reliability, and
- life cycle costs.

It is worth noting that, although the M-E Design Guide describes and provides a specific method that can be used for the determination of alternate design or rehabilitation recommendations for the pavement structure, there are a number of considerations left to the user for final determination. Some of these include drainage provisions, pavement surface friction and texture, special environmental considerations, and local practices that affect the design.

The Guide could not possibly include all of the site-specific conditions that occur in each region of the United States. It is necessary, therefore, for the user to adapt local experience in the use of the M-E Design Guide. For example, local materials and environment can vary over an extremely wide range, even within a state, and especially for a very large state like Texas. The M-E Design Guide attempts to provide procedures for evaluating materials and environment; however, if the M-E Design Guide is at substantial variance with proven and documented local experience, the proven experience should prevail. For example, material requirements and construction specifications are not detailed in this Guide, yet they are an important consideration in the overall design of a pavement structure. The effect of seasonal variations on material properties and evaluation of future traffic for the designed project should be investigated thoroughly.

1.1.4.2 Hierarchical Design Inputs

The hierarchical approach to design inputs is a feature of the M-E Design Guide not found in previous versions of the AASHTO Guide for the design of pavement structures. This new approach provides the designer with considerable flexibility in determining the design inputs for a design project, based on how critical the project is and the available resources. The hierarchical approach is employed with regard to traffic, materials, and environmental inputs. In general, three levels of inputs are provided for each of the input categories.

- **Level 1** inputs provide for the highest level of accuracy and would have the lowest level of uncertainty, or error. Level 1 inputs would typically be used for designing high volume, heavily trafficked pavements or wherever there are dire safety or economic consequences of early failure. Level 1 material inputs require laboratory or field testing, such as the dynamic modulus testing of hot-mix asphalt concrete, site-specific axle load spectra data collections, or nondestructive deflection testing. Obtaining Level 1 inputs requires much more resources and time than other levels.

- **Level 2** inputs provide an intermediate level of accuracy and would be closest to the procedures typically used with earlier editions of the AASHTO Guide. This level could be used when resources or testing equipment are not available for tests required for Level 1. Level 2 inputs typically would be user-selected, possibly from an agency database, could be derived from a limited testing program, or could be estimated through correlations. Examples would be estimating asphalt concrete dynamic modulus from binder, aggregate, and mix properties, estimating Portland cement concrete elastic moduli from compressive strength tests, or using site-specific traffic volume and traffic classification data in conjunction with agency-specific axle load spectra.

- **Level 3** inputs provide the lowest level of accuracy and data collection effort. This level might be used for design where there are minimal consequences of early failure (e.g., lower volume roads). Inputs typically would be user-selected values or typical averages for the region. Examples include default unbound materials resilient modulus values or default Portland cement concrete elastic moduli for a given mix classes used by an agency.

For a given design project, inputs may be entered using a mix of levels, such as Level 1 concrete modulus of rupture, Level 2 traffic load spectra, and Level 3 subgrade resilient modulus. It is important for the designer to understand that no matter what input design levels are used, the computational algorithm for damage is exactly the same. The same models and procedures are used to predict distress and smoothness no matter what level was used to obtain the design inputs.

1.1.5 Pavement Performance

The concept of pavement performance includes consideration of functional and structural performance. This Guide is primarily concerned with functional and structural performance (not included are: reflection of cracks from underlying layers, swelling of subgrade material, or surface friction). The structural performance of a pavement relates to its physical condition, namely fatigue cracking and rutting for flexible pavements and joint faulting and slab cracking for rigid jointed pavements, or other conditions that would adversely affect the load-carrying capability of the pavement structure or would require non-routine maintenance. Several of these key distress types can be directly predicted using mechanistic concepts and are specifically considered in the design process. The functional performance of a pavement concerns how well the pavement serves the highway user. The approach employed is to predict changes in international roughness index (IRI) over time as a function of pavement distress, site conditions, and maintenance.

1.1.6 Traffic Characterization

The Guide considers truck traffic loadings in terms of axle load spectra. The full axle load spectra for single, tandem, tridem, and quad axles are considered. The equivalent single axle load (ESAL) approach is no longer used as a direct design input. In a few cases, axle load spectra are converted internally in the software to ESALs as a means of making use of earlier mathematical models that have not been converted to an axle load spectra basis. The software uses the number of heavy trucks as an overall indicator of the magnitude of truck traffic loadings (FHWA class 4 and above).

The hierarchical levels of traffic data are:

- **Level 1**, the recommended approach for high volume roads, requires the gathering and analysis of site-specific traffic data, including vehicle count by class and by direction and lane. Axle load spectra distributions are developed for each vehicle class from axle weight data collected at or near the project site. Traffic volumes by vehicle class are forecast for the design analysis period, and the load spectra developed for each class are used to estimate axle loads. Default or user input tire contact pressures, tire spacings, and axle spacings may be used.
- **Level 2** is similar to Level 1, requiring site-specific volume and classification data. However, state or regional axle load spectra distributions for each vehicle class may be used to estimate loadings over the design analysis period.
- **Level 3** provides default load spectrum data for a specific functional class of highway. The designer applies these default values to available or estimated vehicle volume data.

1.1.7 Pavement Material Characterization

1.1.7.1 General Considerations

Material characterization guidelines are provided to assist the designer in developing appropriate material property inputs for use in the analysis portion of the design process. The material parameters needed for the design process may be classified into one of three major groups:

- pavement response model material inputs,
- material-related pavement distress criteria, and
- other material properties.

The material inputs to the pavement response model relate to the moduli and Poisson's ratio used to characterize layer behavior within the specific model. Bound materials generally display a linear, or nearly linear, stress-strain relationship. Unbound materials display stress-dependent properties. Granular materials are generally "stress hardening" and show an increase in modulus with an increase in stress. Fine-grained soils are generally "stress softening" and display a modulus decrease with increased stress. Modulus-stress state relations have been developed for granular materials and for fine-grained soils. In practice, assumed Poisson's ratio values are acceptable for routine mechanistic-empirical pavement design based on isotropic elastic structural analysis models. This is true because the parameter has well-defined limits for specific materials types and because the stress, strain, and displacement outputs of the response model are not particularly sensitive to the parameter.

The Enhanced Integrated Climate Model (EICM), a powerful climatic effects modeling tool, is used to model temperature and moisture within each pavement layer and the subgrade. The version of the EICM incorporated in the Guide is based on improvements to an earlier version of the Integrated Climatic Model (Larson and Dempsey 1997). The temperature and moisture predictions from the EICM are used to estimate material properties for the foundation and pavement layers on a semi-monthly or monthly basis throughout the design life. The frost depth is determined, and the proper moduli are estimated above and below this depth.

Material parameters associated with pavement distress criteria are normally linked to some measure of material strength (shear strength, compressive strength, modulus of rupture) or to some manifestation of the actual distress effect (repeated load permanent deformation, fatigue failure of PCC materials).

The "other" category of materials properties constitutes those associated with special properties required for the design solution. Examples of this category are the thermal expansion and contraction coefficients for both PCC and asphalt mixtures.

1.1.7.2 Classes of Materials

For the purposes of this Guide, all pavement materials have been classified into one of the following categories:

- hot-mix asphalt concrete (dense graded, rut resistant, rich bottom layer, etc.);
- open-graded, asphalt-treated permeable base (ATPB) materials;
- cold-mix asphalt (CMA);
- Portland cement concrete;
- cement treated base (CTB) and lean concrete base (LCB) materials;
- open-graded, cement-treated permeable (CTPB) materials;
- nonstabilized aggregate base (AB) materials, also referred to as granular aggregate base (GAB) or coarse aggregate (CA) materials;
- lime modified or lime stabilized layers;
- subgrade soils; and
- bedrock.

1.1.7.3 Levels of Materials Characterization

As mentioned previously, material characterization inputs are defined at three levels with Level 1 requiring laboratory or field testing, Level 2 using correlations with available tests, and Level 3 typically being default values.

1.1.8 Structural Modeling of the Pavement Structure

1.1.8.1 Structural Response Models

Proper structural modeling of new and rehabilitated flexible and rigid pavement structures is the heart of a mechanistic-based design procedure. Structural response models are used to compute critical stresses, strains, and displacements in flexible and rigid pavement systems due to both traffic loads and climatic factors (temperature and moisture). These responses are then utilized in damage models to accumulate damage, month by month, over the design period. The accumulated damage at any time is related to specific distresses such as fatigue cracking or rutting, which is then predicted using a field calibrated cracking model (this is the main empirical part of a mechanistic-empirical design procedure).

The structural models selected for use in this Guide for flexible pavements include the multi-layer elastic program JULEA (Uzan 1976) for linear elastic analysis (LEA). If the user decides to use the Level 1 hierarchical inputs to characterize the nonlinear moduli response of any unbound layer materials (bases, subbases, and/or subgrades), the two dimensional (2-D) finite element program DSC2D is utilized (Desai 2001) to conduct finite element analysis (FEA). The use of FEA is not recommended in the current version of the Guide.

The structural model for rigid pavement analysis is a 2-D finite element program, ISLAB2000 (Khazanovich, et al. 2000). Because thousands of computations of responses are needed for any design, this FEA-based structural model was used as a basis for developing rapid solution neural networks (NN). The neural networks were trained with the thousands of results from ISLAB2000. These neural networks provide accurate and virtually instantaneous solutions for critical responses and were developed so that the large numbers of computations needed could be accomplished rapidly.

These structural response models require several inputs, including the following for each month over the entire design period:

- traffic loading,
- pavement cross-section,
- Poisson’s ratio each layer,
- elastic modulus each layer,
- thickness each layer,
- layer to layer friction (for PCC to base),
- coefficient of thermal expansion (for AC and PCC), and
- temperature gradient and moisture gradient in the PCC slab.

Given these inputs, the structural models produce stresses, strains, and displacements at critical locations in the pavement and subgrade layers.

1.1.8.2 Incremental Damage Accumulation

This design procedure is the first to include the capability to accumulate damage on a monthly basis (or semi-monthly, depending on frost conditions) throughout the entire design period. This approach attempts to simulate how pavement damage occurs in nature, incrementally, load by load, over continuous time periods. By accumulating damage semi-monthly or monthly, the design procedure becomes very versatile and comprehensive. The major advantages of the incremental damage accumulation approach are as follows:

- The design procedure accumulates damage in a similar manner to how it occurs, incrementally, in the field.
- The increments (typically monthly) are selected to match climatic (temperature and moisture) changes that cause changes in layer materials, changes in joint openings, changes in traffic loadings, and material aging and property changes over time.
- The effect of traffic loadings during daytime and nighttime (due to differences in temperature gradients) can be considered.

This approach allows the use of elastic moduli within a given time period, such as a month, that are representative of that time increment. For example, in the heat of summer, the dynamic modulus of an AC surface layer is much lower than in the cold of winter. The resilient modulus of an unbound base course and of the fine-grained subgrade can vary with degree of saturation. This procedure also allows for the aging of paving materials. For example, AC materials age with time, increasing their stiffness. The aging is modeled so that the dynamic modulus (E*) of the AC is constantly increasing over time. The same is true for PCC slabs. The PCC ages and changes strength month by month and year by year over the design period. This change in elastic modulus (E_c) and flexural strength of the PCC is utilized in the design procedure. Thermal gradients are different in summer than in winter months. The developers, and most users, believe that the added capabilities of incremental damage accumulation far outweigh the main disadvantage of increased computation time.

1.1.8.3 Analysis of Trial Design

The approach is iterative and begins with the selection of initial trial designs. A trial design (a set of layers, material properties, and thicknesses) is selected based on past agency experience or on general design catalogs. Each design strategy analyzed includes all details, such as initial estimates of layer thickness, required repairs to the existing pavement, and pavement materials characteristics. The trial sections are analyzed by accumulating incremental damage over time using the pavement structural response and performance models. The outputs of the analysis (the expected amounts of damage over time) are used to estimate distress over time and traffic through calibrated distress models. Modifications are made to the trial strategies and further iterations are performed until a satisfactory design that meets the performance criteria and design reliability is obtained.

1.1.9 Evaluation of Existing Pavements for Rehabilitation

The M-E Design Guide includes procedures and guidance for performing project-level evaluation of pavement structures to be used in identifying rehabilitation alternatives and in rehabilitation design. It also provides guidance for determining those inputs that are considered essential for the different types of rehabilitation design. Some of the input data discussed include:

- traffic lane pavement condition (e.g., distress, smoothness, surface friction, and deflections),
- condition of pavement-shoulder interface,
- pavement design features (e.g., layer thicknesses, structural characteristics, and construction requirements),
- material and soil properties,
- traffic volumes and loadings,
- climatic conditions,
- drainage conditions,
- geometric factors (e.g., bridge clearance),
- safety aspects (e.g., rate and location of accidents), and
- miscellaneous factors (e.g., utilities and clearances).

The project-level evaluation presented in the M-E Design Guide covers three common pavement structures - flexible, rigid, and composite (AC/PCC). Also presented are the procedures used for pavement evaluation and assessing existing pavement condition. Overall pavement condition and problem definition is determined by evaluating the following major aspects of the existing pavement:

- structural adequacy (load related),
- functional adequacy (user related),
- subsurface drainage adequacy,
- material durability,
- shoulder condition,
- variation of pavement condition or performance within a project, and
- miscellaneous constraints (e.g., bridge and lateral clearance and traffic control restrictions).

The structural category relates to those properties and features that define the response of the pavement to traffic loads. The data will be used in mechanistic-empirical design of rehabilitation alternatives. Subsurface drainage and material durability may affect both structural and functional conditions. The type and condition of the shoulder are very important in terms of the selection of rehabilitation type and in affecting project cost. Variation within a project refers to areas where there is a significant variability in pavement condition. Miscellaneous factors, such as joint condition for jointed concrete pavements and reflection cracking for composite pavements, are important to the overall condition of such pavements, but they must be evaluated only where relevant.

1.1.10 Identification of Feasible Rehabilitation Strategies

The M-E Design Guide provides an overview of strategies for the rehabilitation of existing flexible, rigid, and composite pavements. A feasible rehabilitation strategy is one that addresses the causes of pavement distress and deterioration and is effective in both repairing and preventing or minimizing its reoccurrence. A feasible rehabilitation strategy must meet other critical constraints such as length of time for traffic control. Repair treatments are actions taken to restore the pavement's integrity (i.e., to repair the problem definitively), such as filling a pothole. Prevention treatments are actions taken to stop or delay the deterioration process, such as a structural overlay to reduce critical deflections.

A rehabilitation strategy is defined as a combination of repair and preventive treatments (ranging from simple repair treatments such as crack sealing to complex treatments such as the placement of overlays), performed over a defined period of time, to restore the ability of an existing pavement to carry expected future traffic with adequate functional performance.

The M-E Design Guide covers major rehabilitation treatments and strategies typically used in the rehabilitation of flexible, rigid, and composite pavements. It also presents general guidelines for identifying feasible rehabilitation strategies and then for selecting the preferred rehabilitation strategy for use on a specific project.

The following is a list of the common major rehabilitation options that may be applied singly or in combination to obtain an effective rehabilitation strategy:

- reconstruction without lane additions,
- reconstruction with lane additions,
- structural overlay (may include removal and replacement of selected pavement layers),
- non-structural overlay, and
- restoration without overlays (PCC pavements).

1.1.11 Design of Rehabilitation Projects

The M-E Design Guide presents procedures for utilizing the results of the evaluation of the existing flexible, rigid, and composite pavements and the design of AC and PCC rehabilitation for these pavements. The structural design of these rehabilitations is very similar to that of mechanistic-empirical design of new or reconstructed pavement, with the major exception that the existing pavement condition is considered fully.

1.1.12 Design Reliability

Practically everything associated with the design of new and rehabilitated pavements is variable or uncertain in nature. Perhaps the most obvious uncertainty of all is estimating truck axle loadings many years into the future. The inherent variability of the materials used in pavement construction and the actual process of construction also introduce a significant measure of variability. Furthermore, pavements exhibit significant variation in condition along their length as the changes in subgrade support, base construction and compaction, differences in construction of the uppermost layer, etc., work their way to the surface.

Even though mechanistic concepts provide a more accurate and realistic methodology for pavement design, a practical method to consider the uncertainties and variations in design is needed so that a new or rehabilitated pavement can be designed for a desired level of reliability.

Reliability in the M-E Design Guide has been incorporated in a consistent and uniform fashion for all pavement types. An analytical solution that allows the designer to design for a desired level of reliability for each distress and smoothness is available. Design reliability, R is defined as the probability that each of the key distress types and smoothness will be less than a selected critical level throughout the design period.

$$R = P\,[\text{ Distress over Design Period} < \text{Critical Distress Level }]$$

Design reliability for smoothness (IRI) is defined as follows:

$$R = P\,[\text{ IRI over Design Period} < \text{Critical IRI Level }]$$

For example, the reliability for fatigue cracking is defined as follows:

$$R = P\,[\text{ Fatigue Cracking over Design Period} < 20 \text{ percent lane area }]$$

Note that this definition varies from the previous versions of the AASHTO Design Guide in that each key distress is predicted mechanistically and the IRI is specified directly in the definition. Previous guide software defined reliability in terms of the number of predicted equivalent single axle loads to terminal serviceability (N) being less than the number of equivalent single axle loads actually applied (n) to the pavement.

$$R = P\,[\, N < n \,]$$

This older approach produced results that indicated that thicker pavements always increased design reliability. However, this may not always be true for the key performance measures adopted in the M-E Design Guide. In the approach taken in the M-E Design Guide, several design features other than thickness (e.g., HMAC mixture design, dowels for jointed plain concrete pavements, and subgrade improvement for all pavement types) can be considered to improve the reliability estimate of the design.

The designer begins the design process by configuring a trial design. The software accompanying the M-E Design Guide procedure calculates a prediction of key distress types and smoothness over the design life of the pavement. The distresses and smoothness predicted therefore represent mean values that can be thought of as being at a 50 percent reliability estimate (i.e., there is a 50 percent chance that the predicted distress or IRI will be greater than or less than the mean prediction).

For nearly all projects, the designer will require a higher probability that the design will meet the performance criteria over the design life. In fact, the more important the project in terms of consequences of failure, the higher the desired design reliability. The consequence of failure of an urban freeway is far more serious than the failure of a farm-to-market roadway. Often, agencies have used the level of traffic volume or truck traffic as the parameter for selecting design reliability.

Due to the error associated in predicting pavement distresses and smoothness using transfer functions, the actual distress or IRI could be higher or lower than the mean expected value. The distribution of the error term for a given distress or IRI about the mean expected prediction is a function of the many sources of variation and uncertainty, including:

- errors in estimating traffic loadings;
- fluctuations in climate over many years;
- variations in layer thicknesses, materials properties, and subgrade characteristics along the project;
- differences between as-designed and as-built materials and other layer properties;
- errors in the measurement of the distress and IRI quantities; and
- prediction model limitations and errors.

The probability distributions of the key performance measures about their mean values are important in establishing design reliability for each measure. Figure 1-1 illustrates a typical probability distribution for cracking. From this figure, the probability, R, that cracking distress is greater than its associated user-defined failure criteria is computed over the design life and plotted (reliability predictions at an arbitrary level R above the mean predictions are shown as dashed lines in the figure).

The shape and width of the probability distribution of the random variate (each distress and IRI in question) are important and must be known *a priori* in this approach. Distress and IRI are approximately normally distributed over ranges of the distress and IRI that are of interest in design. The standard deviation for each distress type was determined from the model prediction error (standard error of the estimate) from calibration results used for each key distress. Each model was calibrated from Long-Term Pavement Performance (LTPP) and other field performance data. The error of prediction of rutting, for example, was obtained as the difference of predicted rutting and measured rutting results for all sections in the database. This difference, or residual error, contains all available information on the ways in which the prediction model fails to properly explain the observed rutting. As previously stated, the distribution of the distress about the mean prediction was assumed to be normal for each month within the range of interest for design. The standard deviation of IRI was determined using a closed form variance model estimation approach. This approach accounts for all sources previously listed, but not for predicting future traffic growth.

The standard deviation of the distribution of distress is determined as a function of the predicted distress. Figure 1-2 shows an illustration of data from one distress type (slab cracking [CRK]) that shows that the standard deviation of cracking prediction (from calibration data) is related to the mean cracking. Thus, for any mean cracking prediction, an estimate of the standard deviation of cracking can be obtained from this result.

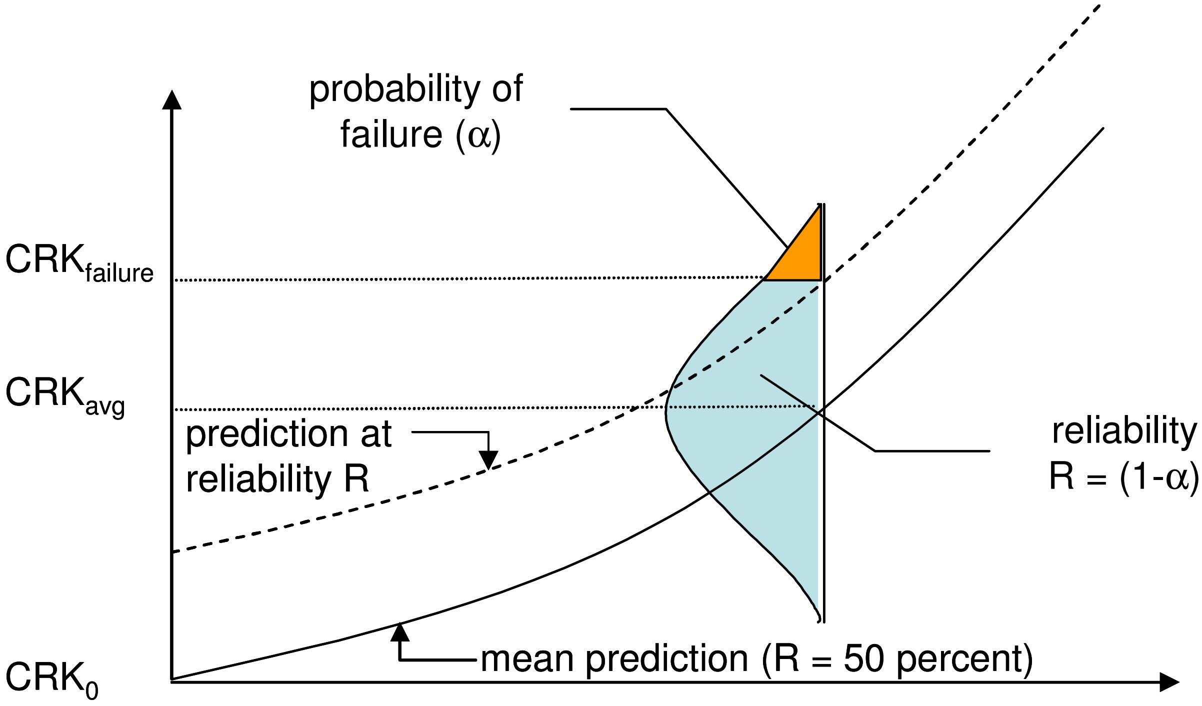


Figure 1-1. Design Reliability Concept for a Given Distress (NCHRP 2004).

Given the mean and standard deviation of a normal distribution, the reliability of the design can be calculated using the following steps:

1. Using the Design Guide cracking model, predict the cracking level over the design period using mean inputs to the model. This corresponds approximately to a “mean” slab cracking due to symmetry of residuals.

2. Estimate cracking at the desired reliability level using the following relationship:

$$CRACK\_P = CRACK_{mean} + STD_{meas} * Zp$$

where

$CRACK\_P$ = Cracking level corresponding to the reliability level p

$CRACK_{mean}$ = Cracking predicted using the deterministic model with mean inputs (corresponding to 50 percent reliability)

STD_{meas} = standard deviation of cracking corresponding to cracking predicted using the deterministic model with mean inputs

Zp = standardized normal deviate (mean 0 and standard deviation 1) corresponding to reliability level p

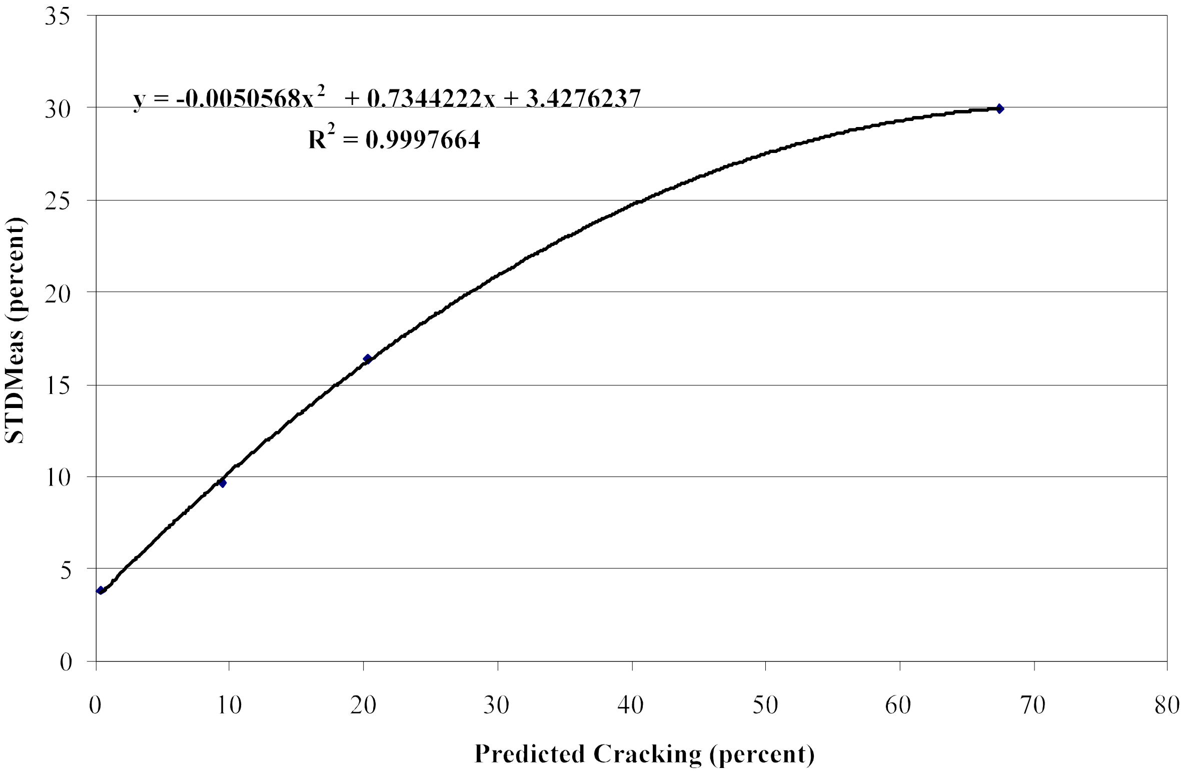


Figure 1-2. Standard Deviation of Measured Cracking vs. Predicted Cracking Obtained from Calibration Data Results (NCHRP 2004).

Desired levels of reliability for each distress can be based on the functional class of the roadway being designed. Some broad guidelines are provided in Table 1-1; however, each agency must establish these values for design.

Table 1-1. Recommended Levels of Reliability for New and Rehabilitation Design.

Functional Classification	Recommended Level of Reliability (%)	
	Urban	Rural
Interstate/Freeways	85 - 97	80 - 95
Principal Arterials	80 - 95	75 - 90
Collectors	75 - 85	70 - 80
Local	50 - 75	50 - 75

Figure 1-3 shows predicted cracking for different reliability levels for a specific jointed plain concrete pavement section in the LTPP program. An increase in reliability level leads to a reasonable increase in predicted cracking. If a pavement designer wants a 90 percent reliability for cracking, then the predicted 90 percent curve must not exceed some preselected critical value of cracking. This level is selected by the designer prior to conducting the pavement design.

For example, Figure 1-3 shows the mean predicted cracking for jointed plain concrete pavement (JPCP) to be 10 percent at the end of 300 months (at 50 percent reliability). The predicted cracking at 90 percent reliability level is 24 percent at the end of 300 months. Comparing these predictions against a user-defined design criterion that the trial design should not have more than 20 percent area cracked at the end of 300 months at a 90 percent reliability level, the design is not adequate. Thus, the design must be iteratively altered and checked so that the mean cracking is low enough to ensure that the design meets the performance criteria.

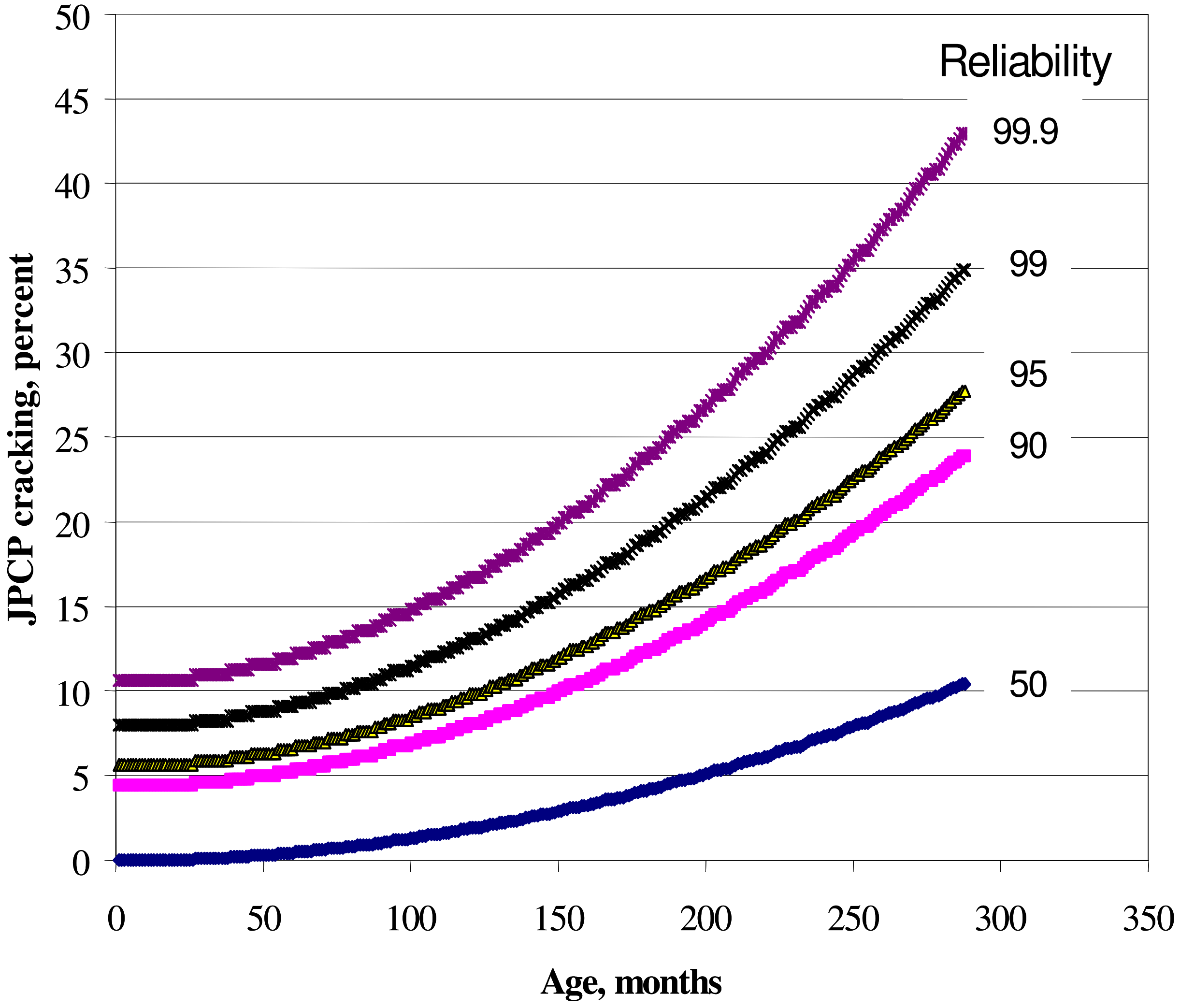


Figure 1-3. Cracking Estimation at Different Levels of Reliability (NCHRP 2004).

Selection of an appropriate level of reliability for design is a challenging task. Some specific guidance is provided as follows:

- The design reliability must be selected for each distress type and for IRI. The levels for each distress type and for IRI do not necessarily need to be equal.
- There is an inherent connection between the levels selected for each distress type and IRI and the level of design reliability. For example, a designer could select either a 97 percent reliability level for cracking with 20 percent area as the critical level, or a lower reliability, say 80 percent, and 10 percent area as the critical level.
- The more important the project in terms of consequences of failure (such as closures of traffic lanes over time causing massive congestion), the higher the design reliability. The consequence of failure of an urban freeway is far more serious than the failure of a farm-to-market pavement. Often, agencies have used the level of traffic volume or truck traffic as the parameter for selecting design reliability.
- The use of smoothness (IRI) as the "overall" design reliability would be similar to the previous use of serviceability index. Use of the IRI as the "main" definition of design reliability by itself is not recommended because failure of the pavement depends more on any key distress maintaining a reasonable value. It is recommended to use all distresses and IRI and to ensure that they all meet the design reliability requirements.
- Selection of design reliability must be done in conjunction with the selection of the critical level of distress or IRI. Joint selection of high design reliability and low distress criteria might make it impossible to obtain an acceptable trial design.

1.1.13 Implementation of the Guide Within an Agency

The M-E Design Guide documentation identifies and discusses the various issues an agency will need to address in order to implement the pavement design procedure described within. Included are discussions and guidelines related to the following:

1. design input data needed, how they will be collected, and establishing a database for inputs;
2. existing and new testing equipment required;
3. computer hardware and software requirements;
4. local calibration and validation of distress models:
    a. establishing a database;
    b. input guidelines for local conditions, materials, and traffic; and
    c. adjusting distress and IRI models; and
5. training requirements.

1.2 MATERIAL PROPERTIES FOR ASPHALT PAVEMENTS

The material properties used for computing the pavement response are (a) the elastic moduli and Poisson's ratio for the linear analysis and (b) elastic modulus of AC, k-parameters

(k_1, k_2, ..) of unbound materials, and Poisson's ratios for the nonlinear finite element analysis. These properties can be entered directly to the program (Level 1 and 2 data) or be evaluated from other descriptive properties (Level 3 data). The moduli of all of these materials are significantly important to the overall performance of the pavement system. For accurate and reliable performance prediction, all pavement materials need to be tested and their parameters derived. With the empirical design procedures, the materials were characterized using California bearing ratio (CBR) tests, Texas triaxial tests (or other types), Marshall or Hveem tests, etc. With the mechanistic-empirical design methods, different types of tests are required. These tests and results are more rational because they address basic material properties, such as modulus. They include testing the asphalt binder to determine G*, testing the AC mix to obtain the dynamic modulus |E*|, and testing the unbound materials to obtain resilient modulus. However, these tests do not address the distresses being evaluated in the design process (cracking or permanent deformation accumulation using transfer functions). In the case of rehabilitation, nondestructive testing (NDT) is required for evaluating the existing condition.

NDT with backcalculation of moduli and the resilient modulus testing have been used by FHWA and several state departments of transportation (DOT) for more than a decade. The performance grading (PG) testing of the asphalt is adopted by most state DOTs. It appears that the dynamic modulus of AC materials is the only "new" test in this design procedure. Therefore, the move to adopt the testing required by the Guide should not take long or be problematic. Recommendations for equipment and training for testing are available from FHWA.

As the material moduli control the pavement response in terms of stresses, strains, and deformations, it is of prime importance to use the parameters that correspond to local materials (together with the local environmental conditions). The default values included in the Guide may not be accurate enough for some local materials. Therefore, the testing of local materials and obtaining the required parameters for use in the M-E Design Guide should be a high priority task in the implementation of the Guide.

The following section presents a brief review of the dynamic modulus and some results obtained in a separate study.

1.2.1 Dynamic Modulus of AC Mixes

The results of the dynamic modulus test are entered only for Level 1 data entry. For Levels 2 and 3, the master curve is estimated from a predictive equation based on gradation and mix properties. According to Fonseca and Witczak's (1996) analysis of variance, the equation predicts the modulus within a factor of about 2. In the following, we will present the predictive equation and compare the prediction with actual laboratory data.

The dynamic modulus master curve is represented by the sigmoidal function described by (Equation 2.2.1 in the M-E Design Guide manual):

$$\log(|E^*|) = \delta + \frac{\alpha}{1 + e^{\beta + \gamma(\log t_r)}}$$

where

|E*| = Dynamic modulus

t_r = Time of loading at the reference temperature (computed as the reciprocal of the frequency)
δ = Minimum value of |E*| (for very long loading times and high temperatures)
$\delta+\alpha$ = Maximum value of |E*| (for very short loading times and low temperatures)
β, γ = Parameters describing the shape of the sigmoidal function

The sigmoidal function describes the time dependency of the modulus at the reference temperature. The time-temperature equivalency is described by shift factors as follows:

$$t_r = \frac{t}{a(T)} \quad or \quad \log(t_r) = \log(t) - \log\left[a(T)\right]$$

where
t_r = Time of loading at the reference temperature
t = Time of loading at a given temperature of interest T
$a(T)$ = Shift factor as a function of temperature
T = Temperature of interest

The fitting parameters δ and α depend on aggregate gradation, binder content, and air void content. The fitting parameters β and a(T) depend on the characteristics of the asphalt binder.

$$\delta = -1.249937 + 0.02932\rho_{200} - 0.001767(\rho_{200})^2 - 0.002841\rho_4 - 0.058097V_a - 0.802208\left[\frac{Vb_{eff}}{Vb_{eff} + V_a}\right]$$

$$\alpha = 3.871977 - 0.0021\rho_4 + 0.003958\rho_{38} - 0.000017\rho_{38}^{\;2} + 0.005470\rho_{34}$$

$$\beta = -.603313 - .393532\log(\eta_{T_r})$$

$$\log[a(T)] = c\left(\log(\eta) - \log(\eta_{T_r})\right)$$

$$\gamma = 0.313351$$
$$c = 1.255882$$

where
ρ_{34} = Cumulative % retained on the 3/4 inch sieve
ρ_{38} = Cumulative % retained on the 3/8 inch sieve
ρ_4 = Cumulative % retained on the No. 4 sieve
ρ_{200} = Percent passing the No. 200 sieve
η = Viscosity at the age and temperature of interest
η_{Tr} = Viscosity at the reference temperature
Vb_{eff} = Effective binder content, % by volume
V_a = Air void content

The following laboratory data for mix “TxDOT Bryan” was obtained from “Evaluation of Simple Performance Tests on HMA Mixtures from the South Central United States” by Amit

Bhasin, Joe W. Button, and Arif Chowdhury, Report FHWA/TX-03/558-1, Sep 2003. The gradation of the mix is shown in Figure 1-4 (from which the following values can be extracted: $\rho_{34} = 0$, $\rho_{38} = 33.1$, $\rho_4 = 65.9$, and $\rho_{200} = 7$). The air void and volume of effective binder were: $V_a = 7$, $Vb_{eff} = 8.8$. The binder used was a PG-64-22 (with the corresponding rolling thin film oven test (RTFO) A = 10.98 and viscosity temperature susceptibility (VTS) = -3.68, see M-E Design Guide manual, Chapter 2).

Using the above variables, a master curve is computed and shown in Figure 1-5. The dynamic modulus test results are presented in Table 1-2 (two replicates). They are shown in Figure 1-5. In order to compare the computed master curve with the test results, the test results were shifted (horizontally) using the shift factor a(T) of the predictive equation. It is seen that the predicted dynamic modulus is lower by a factor of 2 to 3 than the measured values. This is within the expectations of the predictive equation.

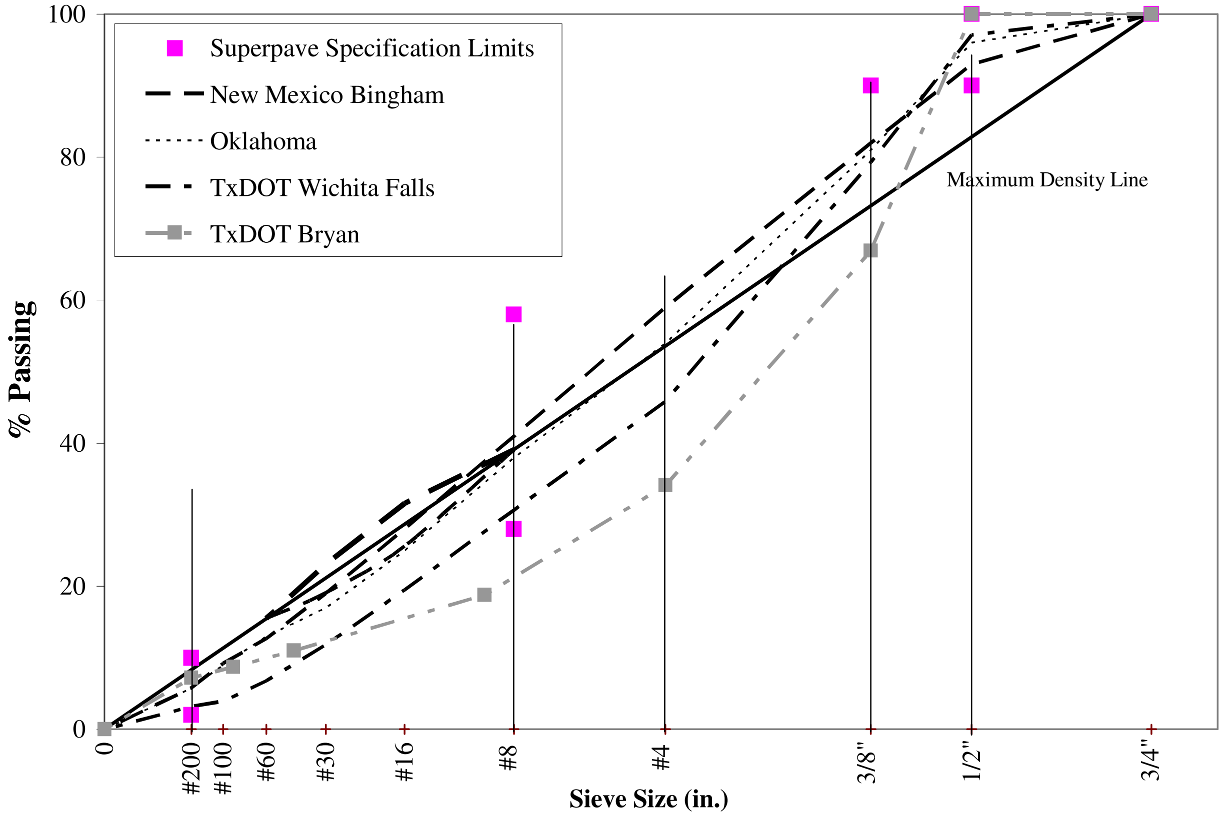


Figure 1-4. Gradation of Mixes with 1/2" Maximum Nominal Aggregate Size.

Finally, Figure 1-6 from the above report illustrates the wide variation in the dynamic modulus, using different aggregates, gradations, and binders. This wide range and the under-prediction shown in Figure 1-5 suggest that local master curves need to be generated and used in the implementation of the Guide.

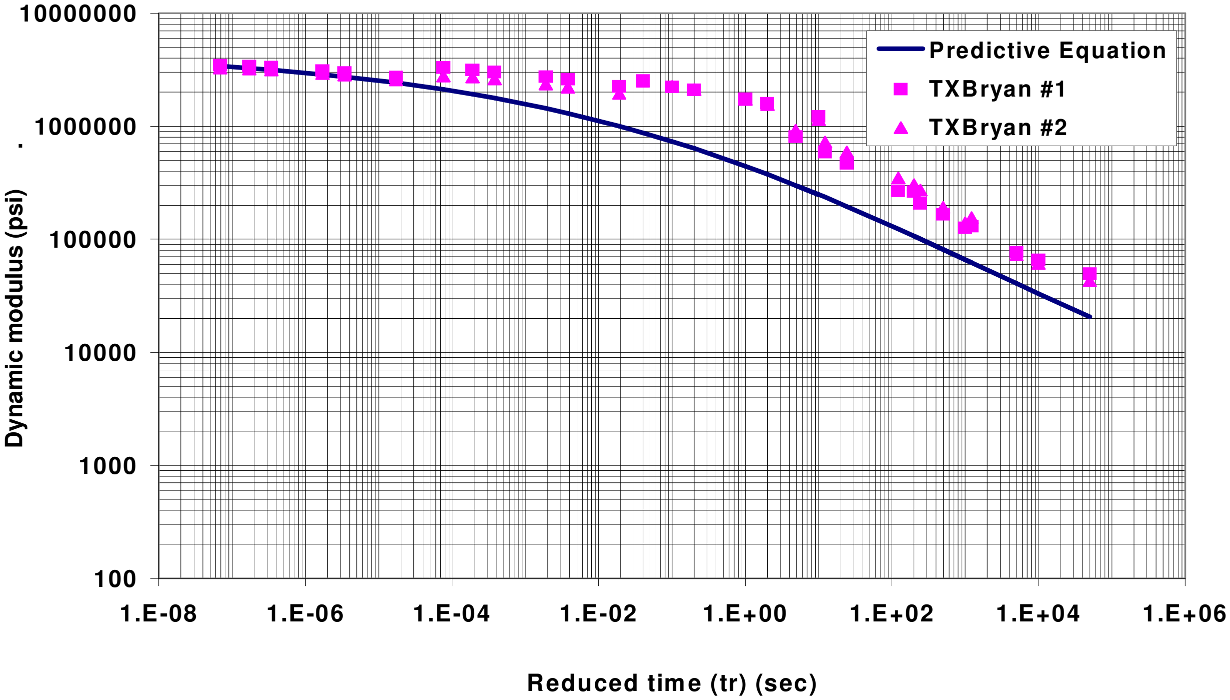


Figure 1-5. Predicted Master Curve.

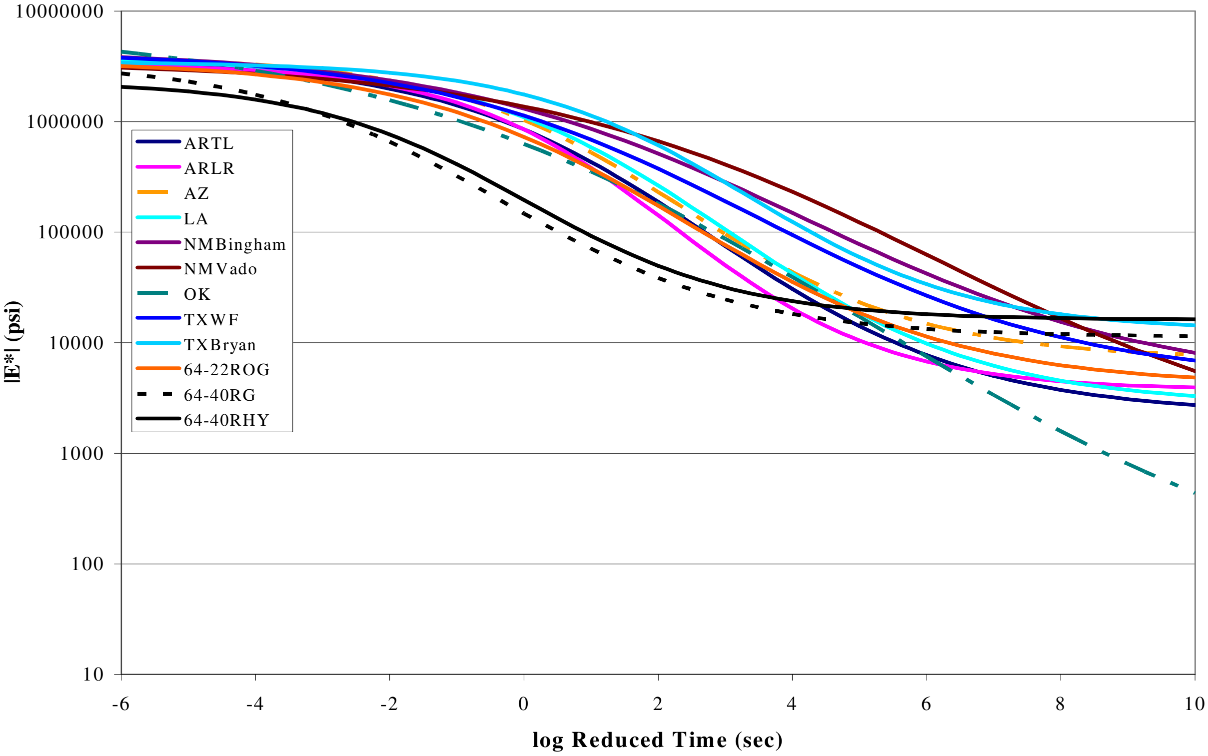


Figure 1-6. Master Curve for Mixtures.

Table 1-2. Dynamic Modulus Data for TXBryan.

Temp. (°F)	Freq. (Hz)	TXBryan #1			TXBryan #2		
		$\lvert E^* \rvert$ (psi)	ϕ (degrees)	$\lvert E^* \rvert / \sin \phi$ (psi)	$\lvert E^* \rvert$ (psi)	ϕ (degrees)	$\lvert E^* \rvert / \sin \phi$ (psi)
14.0	25	3472348	0.77	258382342	3259142	0.19	982826799
14.0	10	3406500	3.25	60086799	3201852	2.75	66735907
14.0	5	3319333	4.04	47114772	3131074	3.69	48651301
14.0	1	3098295	5.62	31637219	2919754	5.19	32276835
14.0	0.5	2985891	6.27	27339897	2823449	5.66	28628556
14.0	0.1	2720037	7.89	19814615	2559770	7.37	19954722
39.9	25	3299608	1.27	148871336	2766159	1.83	86619995
39.9	10	3144272	3.9	46229752	2713945	4.47	34821811
39.9	5	3012143	5.04	34286187	2606182	5.14	29089631
39.9	1	2741213	6.76	23287108	2355702	7.09	19086091
39.9	0.5	2610098	7.67	19555868	2211825	7.81	16276856
39.9	0.1	2243008	9.87	13085011	1940314	10.45	10697256
70.0	25	2530908	5.51	26357701	2491748	5.94	24077273
70.0	10	2224733	8.72	14674044	2245184	9.25	13967856
70.0	5	2095795	9.48	12725028	2106092	10.89	11147888
70.0	1	1743353	14.15	7131359	1728124	14.61	6851291
70.0	0.5	1597010	16.29	5693600	1548132	16.32	5509257
70.0	0.1	1219477	20.85	3426371	1145073	21.92	3067257
100.0	25	808150	23.68	2012398	921715	22.26	2433007
100.0	10	590448	27.37	1284164	723883	26.76	1607598
100.0	5	467457	33.34	850501	589288	31.06	1142172
100.0	1	267450	34.05	477754	348090	36.75	581746
100.0	0.5	206534	34.57	363900	271075	39.44	426701
100.0	0.1	130244	31.78	247289	154755	40.35	239022
130.0	25	262373	31.47	502701	303274	32.02	572029
130.0	10	166068	28.23	351136	190289	31.42	365060
130.0	5	126473	33.21	230755	139961	33.65	252656
130.0	1	76580	29.29	156496	72954	33.95	130534
130.0	0.5	65557	28.94	135320	60771	33.79	109213
130.0	0.1	49458	26.33	111534	42786	30.23	84992

1.3 CRCP MODULE

The present AASHTO approach to the design of continuously reinforced concrete pavements (CRCP) focuses on the design of the steel reinforcement relative to the development of the crack pattern, with little emphasis on how characteristics of the crack pattern influence pavement performance. Recent developments associated with the proposed mechanistic-based M-E Design Guide have provided considerable improvement on this situation and reinforced the utility of mechanistic relationships between the characteristics of the crack pattern, material properties, and pavement response parameters. This is a major step forward in improving pavement performance predictions.

In contrast to the present design guide, the proposed M-E Design Guide focuses on the predictability of CRCP performance using key mechanistic relations that relate the parameters distribution of crack spacing, crack width, load transfer efficiency, and "wear out" of the transverse cracks, and support conditions to pavement response in terms of traffic and environmental loading as the core of a new approach to the design procedure for CRC pavement. The major structural distress of CRCP is the punchout, which consists of an area enclosed by two closely spaced transverse cracks, a short longitudinal crack, and the edge of the pavement or a longitudinal joint that is associated with loss of support.

1.3.1 CRCP Punchout Mechanism

The causes and factors associated with CRCP punchouts have been the topic of many investigations. One of the early studies describes the mechanism of edge punchout based on the field investigations of punchout distress on CRCP in Illinois (Darter et al. 1979). This study showed the development of high tensile stress at the top of the slab about 3 ft (1 m) from the longitudinal edge of the slab as a result of poor load transfer at the surrounding transverse cracks. Crack spacing has also been shown to significantly affect the magnitude of the critical tensile lateral stresses on the top of the slab. A mechanistic relationship was established between crack spacing and level of load transfer efficiency across the transverse cracks in the M-E Design Guide.

Deterioration of load transfer effectively isolates the loaded portion of the slab between the deteriorated transverse cracks from the adjacent pavement. As a result, only a narrow strip of concrete, bound by two transverse cracks, carries the wheel load. This situation leads to development of high top tensile stresses. As repetitive heavy truck loading continues, a short longitudinal fatigue crack forms between the two transverse cracks. Any further wheel loads cause the portion of the concrete slab bounded by the transverse cracks to develop a short longitudinal crack and the pavement edge to break off and settle into the eroded area, resulting in an edge punchout. The short description above basically outlines the process behind the development of the CRC design procedure in the M-E Design Guide.

1.3.2 Fatigue Damage Modeling

Using the critical wheel load stresses, accumulated fatigue damage is estimated and used to predict punchout distress. According to Miner's hypothesis (Miner 1945), each truck axle load passage contributes to overall pavement damage that accumulates over time.

Since the damage prediction is cumulative as a function of tensile stresses at different instances over the life of the pavement, accurate prediction of stress changes over the design life is important. The analysis period is subdivided into time increments based on subgrade support and climatic conditions relative to their effect on crack width and load transfer. Different percent steel resulted in different mean crack spacing and, hence, different load transfer efficiency (LTE) of the transverse cracks.

1.3.3 Transverse Crack Spacing Characteristics

Within 2 years after construction, CRCP develops a transverse cracking pattern, typically spaced 0.6 to 1.8 m (2 to 6 ft) apart. For newly constructed CRCP, transverse cracks are tightly held together by the longitudinal reinforcement. Absence of transverse contraction joints and a well-defined pattern of transverse cracks are the major attributes that identify CRCP. Mechanistic-empirical design procedures for CRCP are highly amiable to characterization of variations in major design parameters so that a new or rehabilitated pavement can be designed for a desired level of reliability. Transverse cracking is an important CRCP design parameter affecting prediction of crack width, crack load transfer efficiency, and critical stresses leading to longitudinal cracking and punchout development. For the proposed Guide, a theoretical model utilizing a Weibull distribution was developed to characterize along the section transverse crack spacing frequency distribution.

1.3.4 CRCP Sensitivity and Calibration

It is clear that several parameters relative to the punchout development process and the prediction of the crack pattern should be considered for sensitivity analysis and design calibration. In terms of the punchout mechanism, the key parameters that contribute to pavement performance are load transfer, crack or joint stiffness, slab thickness, subbase friction and strength, and concrete stiffness and strength. Specifically, the sensitivity of performance should be checked relative to the effect of slab thickness, concrete strength, crack width (relative to concrete thermal and shrinkage effects), and reinforcing steel characteristics. In terms of calibration efforts, the coefficients associated with wear-out of aggregate interlock, shear capacity of a transverse crack relative to crack opening, load transfer contributions of the reinforcing steel, and the punchout performance and reliability equations are prime candidates for consideration.

Relative to crack pattern prediction, concrete strength, shrinkage and temperature gradients, position of the steel reinforcing, steel percentage, and the other parameters are key parameters to be included in the sensitivity analysis. Most of these parameters can be varied in a similar manner in CRCP 10 to gain a level of confidence and comparability between it and the proposed method adopted in new design guide.

The goodness of fit between the theoretical crack spacing frequencies generated using the Weibull distribution and CRCP 10 to selected observed field frequencies can be considered as part of the calibration of the crack pattern prediction capability. In this regard, minimum crack spacing and the correlation coefficient are prime calibration parameters and can be used to fine-tune the crack pattern prediction.

One major part of this project will be to conduct a sensitivity analysis to determine which data elements, within typical TxDOT ranges, have the most impact. However, we also want to identify those elements that may have some impact but are expensive or difficult to collect.

1.3.5 M-E Design Guide CRC Pavement Design Features

1.3.5.1 Slab Thickness

Slab thickness is an important design feature from a performance and slab stiffness standpoint. In general, as the slab thickness of a CRC pavement increases the capacity to resist critical bending stresses increases, as does the slab's capability to transfer load across the transverse cracks. Consequently, as slab thickness increases, performance improves since slab stiffness increases concomitant to enhanced load transfer capability afforded by the additional slab thickness. Slab thickness must be selected within the context of other design features including transverse crack width, percent steel reinforcement, PCC mixture properties, and base type and stiffness, as well as weather conditions at the time of construction. In other words, depending upon the construction conditions and coarse aggregate type, one slab thickness may be adequate for a given set of design features but not for another set of design features. The goal is to select the minimum thickness that provides acceptable levels of aggregate interlock wear-out, punchout development, and smoothness (IRI) over the design period at the desired level of reliability.

1.3.5.2 Transverse Crack Width

The width of the transverse crack is the primary CRC pavement design feature. It is the feature that is fundamental to many aspects of CRC pavement performance and is used to determine the amount of steel used for design. The smaller the crack width, the greater the capacity of the crack to carry shear stress between adjacent slab segments. Crack width is a key focus of the crack pattern since it has a dominant role in controlling the degree of load transfer provided at the transverse cracks. Ultimately, the crack width average and distribution control the life and the quality of CRC pavement performance.

1.3.5.3 Longitudinal Reinforcement

Longitudinal steel is an important design parameter since it is used to control the opening of the transverse cracks. It is also critical from the standpoint of its effect on crack spacing. Field studies have shown that the longer the crack spacing the greater the potential of widened transverse cracks. The reinforcement in CRC pavement causes a restraining effect to contraction strain that increases as the percentage of steel increases and, relative to the Q value ($4p/d_b$), is one of the major steel-related design factors affecting crack development. Decreased crack spacing is associated with increased steel percentages. U.S. experience has indicated that steel percentages of 0.55 to 0.70 have provided suitable cracking patterns and performance in CRC pavement systems. In this regard, it is important to consider the effect of steel content. Steel content is determined within the context of several other design features such as slab thickness, crack width, PCC materials properties, and base type and stiffness. In other words, a specific percentage of steel may be adequate for a given set of design features and inadequate for another set of design features, particularly with respect to different coarse aggregate types. The goal is to select the minimum steel content that provides an acceptable level of transverse crack widths and resistance to punchout development over the design life at the desired level of reliability. The direct consideration of top-down cracking has made base support, load transfer, and crack width even more critical. Truck axle loading causes a longitudinal bending stress at the top of the slab that increases as the load transfer diminishes over time, which can lead to serious top-down transverse cracking.

1.3.5.4 Transverse Crack Load Transfer Efficiency

The load transfer of transverse cracks is a critical factor in controlling development of longitudinal cracking. Field studies have shown that close transverse crack patterns are associated with small crack widths that maintain a high resistance to wear-out of aggregate interlock. Maintaining load transfer of 92 percent or greater will minimize loss of aggregate interlock over the design life of the pavement and limit the development of punchout distress. Punchout distress is the most critical factor in controlling roughness of CRCP. Crack load transfer efficiency can be selected within a variety of combinations of several other design features including slab thickness, percent steel, crack width, crack spacing, PCC materials properties, and base type and stiffness. The goal is to select the crack width and slab thickness corresponding to a load transfer of 92 percent at a suitable level of steel that provides an acceptable level of punchout development and smoothness over the design life at the desired level of reliability.

1.3.5.5 Modeling Load Transfer in the M-E Design Guide

As previously noted, loss of transverse crack load transfer is a precursor of punchout development. As load transfer wears out, top transverse stresses increase, potentially leading to the formation of a short longitudinal crack between two adjacent transverse cracks as a result of heavy axle load repetitions. Consequently, a relation between the CRC pavement design parameters such as crack spacing, crack width, and load transfer efficiency of the transverse cracks is needed to adequately predict punchouts as a function of traffic.

Crack load transfer efficiency due to aggregate interlock can be determined based on:

- Crack width: Depends on crack spacing, concrete set temperature, steel content, PCC shrinkage and temperature change, and subbase friction.
- Aggregate interlock wear-out: Depends on crack width and governs the ability of the crack to transfer applied loads from one side of the crack to the other.

1.3.5.6 Crack Width Component

The width of the transverse crack is fundamental to many aspects of CRC pavement performance, since it plays a dominant role in controlling the degree of load transfer provided across a crack, which serves as the criteria for the required design steel content. Crack width is affected by several time-dependent design parameters, as shown in the following formula for a single layer of steel:

$$cw_{ki} = L_k\left(\varepsilon_{shri} + \alpha_{PCC}\Delta T_{\varsigma m}\right) - L_k \frac{c_{2ki}}{E_{PCCi}}\left(\frac{L_k U_m P_b}{c_{1ki} d_b} + C\sigma_{0ki}\left(1 - \frac{2h_s}{h_{PCC}}\right) + \frac{L_k}{2} f\right)$$

where

cw_{ki} = Average crack width at the depth of the steel for each time increment *i* and crack spacing *k*, mm (mils)

L_k = k^{th} crack spacing, mm

ε_{shri} = Unrestrained concrete drying shrinkage at the depth of the steel for each time increment *i* and crack spacing *k*

α_{PCC} = Concrete coefficient of thermal expansion (CoTE), $°C^{-1}$ ($°F^{-1}$)

$\Delta T_{\varsigma m}$ = Seasonal drop in PCC temperature at the depth of the steel °C (°F)

$c_{1\,ki}$ = First bond stress coefficient for time increment *i* and crack spacing *k*

$c_{2\,ki}$ = Second bond stress coefficient for each time increment *i* and crack spacing *k* (typical range = 0.7 to 0.9)

$= a_i + \frac{b_i}{k_{li}} + \frac{c_i}{L_k^2}$

a_i = $0.7606 + 1772.5(\varepsilon_{tot\text{-}ci}) - 2e06(\varepsilon_{tot\text{-}ci})^2$

b_i = $9e08(\varepsilon_{tot\text{-}ci}) + 149486$

c_i = $3e09(\varepsilon_{tot\text{-}ci})^2 - 5e06(\varepsilon_{tot\text{-}ci}) + 2020.4$

$\varepsilon_{tot\text{-}ci}$ = Total strain at the depth of the steel for the time increment (*i*) (typical range = 150 to 600 micro-strains)

k_{li} = Bond slip coefficient

$E_{PCC\,i}$ = Concrete modulus of elasticity for the time increment *i*, kPa (psi)

P_b = Percent steel, fraction

d_b = Reinforcing steel bar diameter, mm (in.)

U_m = Peak bond stress, kPa (psi)

h_{PCC} = PCC slab thickness, mm (in.)

h_s = Depth to steel, mm (in.)

f = Subbase friction coefficient based on subbase type from test data or using M-E Design Guide recommendations

C = Bradbury's correction factor for slab size (Bradbury 1938)

$\sigma_{0\,ki}$ = Westergaard nominal environmental stress factor for slab curling and warping for each time increment *i*, kPa (psi)

$= \frac{E_{PCCi}\varepsilon_{tot-\Delta m}}{2(1-\mu_{PCC})}$

where

μ_{PCC} = Poisson's ratio

$\varepsilon_{tot\text{-}\Delta\,m}$ = Equivalent total strain difference between the pavement surface and slab bottom

For any given project, crack widths vary widely along the project from crack to crack. One may consider this variability to correlate with the variability in crack spacing. Figure 1-7 shows differences in crack width predicted for three different crack spacings, assuming all other parameters to be constant. Fluctuations in crack width over the design life are affected by changes in thermal and moisture strains for different environmental seasons. However, gradual crack width opening is attributed primarily to drying shrinkage.

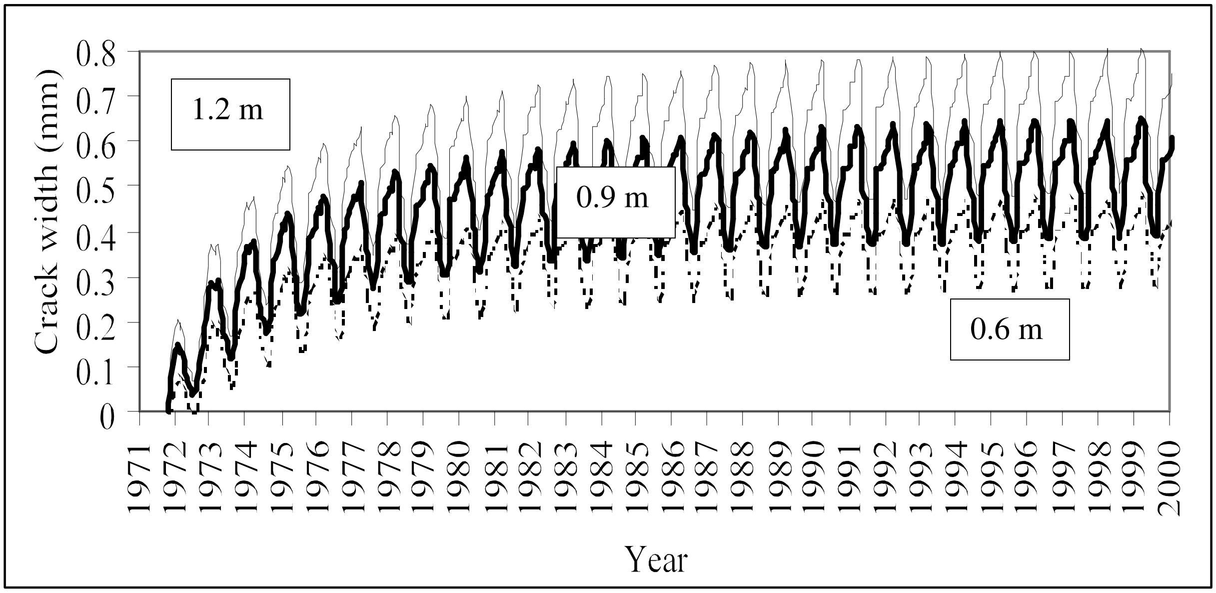


Figure 1-7. Time History of Changes in Crack Opening over Pavement Life Predicted Using Data for LTPP GPS-5 Section 175849 in Illinois (Crack Spacings Indicated).

1.3.5.7 Aggregate Interlock Wear-out Component

The ability of a crack to carry load is described in terms of shear capacity, which is directly related to aggregate interlock and the thickness of the slab. As a crack opens and closes, its ability to transfer shear load or shear capacity can be described using the following relation:

$$s_{oi} = 0.0312\,(h_{PCC})^{1.4578}\,e^{-(0.032)cw_{ki})}$$

where

s_{oi} = Dimensionless seasonal shear capacity based on crack width
h_{PCC} = Thickness of the slab, mm (in.)
cw_{ki} = Crack width as a function of time from the equation in section 1.3.5.6, mm

Based on the above formula, shear capacity varies seasonally with the crack opening and affects crack load transfer efficiency over the life of the pavement. However, as the concrete slab is subjected to axle load applications, vertical crack surfaces are subjected to repetitious shear loading between the two sides of the crack that leads to aggregate wear-out and decreases crack load transfer capacity. Therefore, the computed crack shear capacity is reduced each time a load is applied across a crack. The total shear capacity of the transverse cracks for any given instance in pavement life *i* can be characterized using the following formula:

$$s_i = s_{oi} - \sum_{i-1}^{i-1} \sum_{j} \left(0.069 - 2.75e^{-cw/h_{pcc}}\right)\left(\frac{n_{jt}}{10^6}\right)\left(\frac{\tau_{ij}}{\tau_{refi}}\right)$$

where

s_i = Total crack shear capacity at time increment *i*

s_{oi} = Crack shear capacity based on crack width for time increment *i*

cw_i = Crack width for time increment *i*

h_{PCC} = Thickness, mm (in.)

n_{ji} = Number of axle load applications for time increment *i*, load level *j*

τ_{ij} = Shear stress on the transverse crack at the corner due to load level *j* applied during time increment *i*, kPa (psi)

$\tau_{ref\,i}$ = Reference shear stress derived from the PCA test results for time increment *i*, kPa (psi)

Coefficients in the previous two equations were modified from the original values used in the reference (Zollinger et al. 1998) based on the analysis of the additional data from CRCP sections from the LTPP GPS-5 experiment. Limited verification of the wear-out model is presented in Appendix B.

1.3.5.8 Load Transfer Prediction Model

To relate crack shear capacity to crack load transfer efficiency, an intermediate parameter that is a function of the aggregate interlock factor (AGG) called a J factor is employed:

$$Log\,(J_{c\,ki}) = ae^{-e^{-\left(\frac{J_s - b}{c}\right)}} + de^{-e^{-\left(\frac{s_{ki} - e}{f}\right)}} + ge^{-e^{-\left(\frac{J_s - b}{c}\right)}}e^{-e^{-\left(\frac{s_{ki} - e}{f}\right)}}$$

where

$J_{c\,ki}$ = Stiffness of the transverse crack for time increment *i* and crack spacing *k*

= AGG/*kl* (dimensionless aggregate interlock factor)

a,b,c,d

e,f,g = Regression coefficients for dimensionless stiffness (J) equation

s_{ki} = Dimensionless shear capacity for time increment *i* and crack spacing *k*

J_s = Stiffness of the shoulder/slab longitudinal joint with suggested values noted in Table 1-3.

Table 1-3. Stiffness of the Shoulder/Slab Longitudinal Joint.

Shoulder Type	J_s
Granular	0.04
Asphalt	0.04
Tied PCC	4

Load transfer efficiency on the transverse crack at any instance of time can be found on the basis of the $J_{c\,i}$ parameter using the modified formula originally developed by Ioannides (Ioannides 1996), as following:

$$LTE_{TOTki} = 100\left[1-\left[1-\frac{1}{1+\log^{-1}\left[\left(0.214-0.183\frac{a}{\ell_i}-\log\left(J_{cki}\right)-R\right)/1.18\right]}\right]\right]$$

where

$LTE_{TOT\,ki}$ = Total crack LTE due to aggregate interlock, steel reinforcement, and base support for time increment i and crack spacing k, percent

ℓ_i = Radius of relative stiffness computed for time increment i, mm (in.)

a = Radius for a loaded area, mm (in.)

R = Residual dowel-action factor to account for residual load transfer provided by the steel reinforcement (#5 bar = 0.5, #6 bar = 1.0, #7 bar = 1.5)

The R factor in the LTE equation is an empirical LTE adjustment to account for the effect of the size of reinforcing bar used in the pavement.

Combining the previous two equations, the effect of stiffness due to aggregate interlock can be taken into account as illustrated in Figure 1-8. The effects of aggregate interlock are shown as a function of joint or crack opening. The achievement of a greater load transfer capability can only be accomplished through aggregate interlock and small crack openings. In other words, high load transfer conditions are achieved through aggregate interlock. Perhaps the presence of steel reinforcement makes some contribution to the transfer of load from one segment to another, but it is clear that crack width is critical to achieving and maintaining high load transfer conditions.

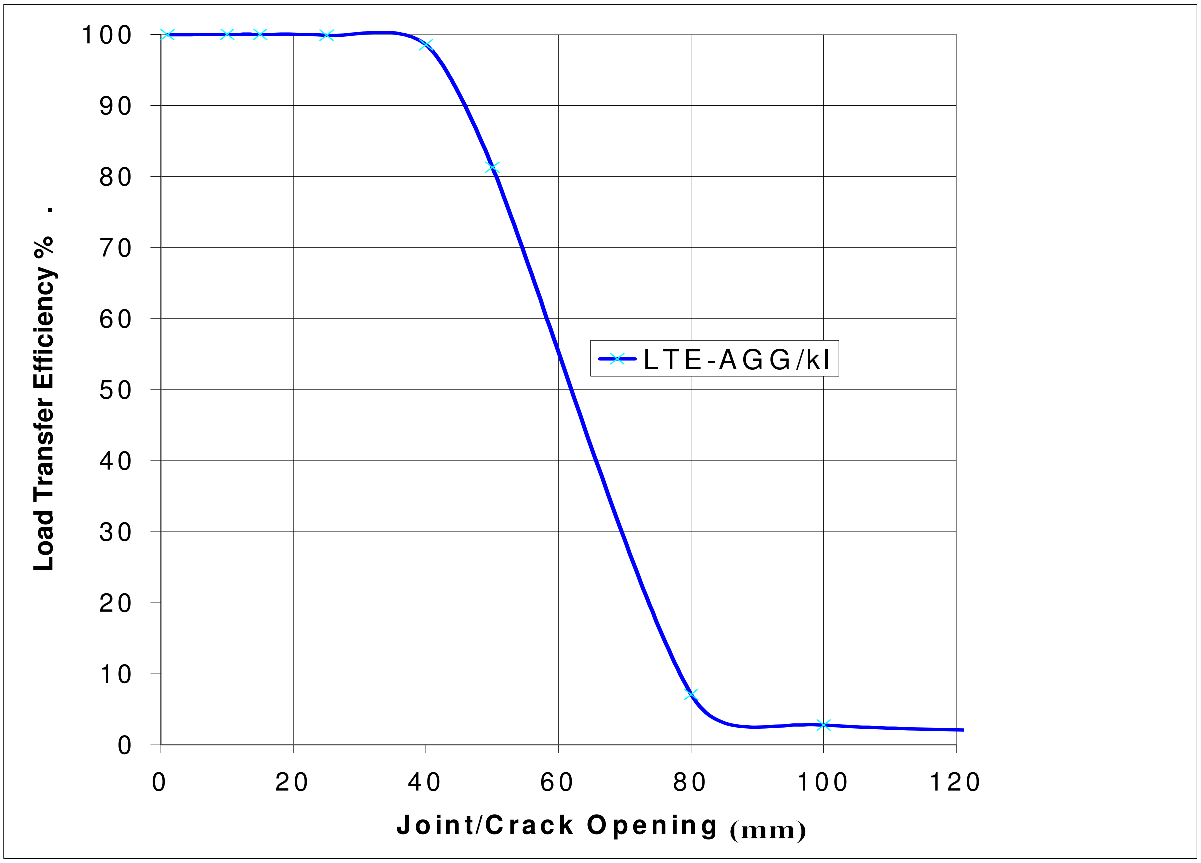


Figure 1-8. Load Transfer/Crack Stiffness Relationship.

CHAPTER 2 - SENSITIVITY ANALYSIS

Before any implementation strategy can be developed, an analysis of the sensitivity of the input parameters on the pavement design needs to be made.

2.1 GENERAL SENSITIVITY STUDY

The M-E Design Guide software was developed to be relevant and calibrated to all climatic zones in the country, and it includes variables that may only be important to regions that are much colder, use materials with different properties, or are otherwise much different than conditions in Texas. In order to determine which variables are most important to TxDOT, especially if the data on these variables are costly to collect, a default set of inputs were developed and two types of sensitivity analyses were conducted.

In this first, general sensitivity analysis, a default set of inputs was generated and one variable at a time was varied through a reasonable range for pavements in Texas. Input files were developed that contained all the M-E Design Guide inputs. Values were based on using the middle of a specification range, typical values, best guesses, and values typically used by TxDOT. That is, although the full range of a variable may be between 0 and 100 percent, if the TxDOT specification mandates the value be between 20 and 40 percent, the base value was set to 30 and the minimum and maximum value were set at 20 and 40 percent, respectively. Prior to beginning the analysis, the tables of proposed values were submitted to and reviewed by TxDOT. As part of this project, the base (default) files will be presented to TxDOT.

2.1.1 Experiment Design

Because Texas contains several different climatic areas and because pavement designs use different materials in these areas, the Project Monitoring Committee (PMC) directed the researchers to investigate a typical pavement representing a dry, cold climate and a wet, warm area. The Dry-Cold (DC) input files represent pavements between Amarillo and Lubbock, while the Wet-Warm (WW) files represent pavements between Beaumont and Houston. Sometimes, different layers were used depending on whether the pavement is in the Dry-Cold or Wet-Warm area. These differences are discussed in more detail under the specific pavement type.

2.1.2 Asphalt Concrete (AC) Pavements

Hot-mix asphalt concrete pavements are used throughout Texas on low, medium, and high volume routes. Because of the different demands of heavier traffic, the thickness can vary from seal coat pavements, which have no HMAC and rely on the seal coat to protect the supporting base layers, to thin pavements with 1 to 2 inches of HMAC, all the way to thick pavements of 14 inches or more of HMAC. Since these pavements may have a different set of significant variables, the analysis was conducted on thin, intermediate, and thick HMAC pavements. The M-E Design Guide does not analyze seal coat pavements.

The M-E Design Guide input requires the types and thicknesses of each layer. Since the analysis was to be conducted on specific thicknesses of HMAC, or stone matrix asphalt (SMA), pavement sections from the flexible pavement database project were selected that had those thicknesses and traffic levels. The pavement layers were analyzed with FPS19W to ensure that these designs were adequate. Some layer thicknesses were modified to be used in the specified locations. The pavement layers in Table 2-1 were used to evaluate the M-E Design Guide for asphalt concrete pavements.

Table 2-1. Layer Types and Thicknesses Used in M-E Pavement Design Sensitivity Analysis of Asphalt Concrete Pavements.

Layers	Dry-Cold			Wet-Warm		
	AC-Thin	AC-Intermediate	AC-Thick	AC-Thin	AC-Intermediate	AC-Thick
Surface	1.5" HMAC	8.5" HMAC	4.0" SMA	1.5" HMAC	8.5" HMAC	4.0" SMA
2nd AC Layer	-	-	14.0" Rut Resistant	-	-	14.0" Rut Resistant
Granular Base	6.0" Crushed Stone	6.0" Crushed Stone	-	8.0" Crushed Stone	6.0" Crushed Stone	-
*Treated Layer	8.0" Lime Treated	6.0" Lime Treated	8.0" Lime Treated	8.0" Lime Treated	6.0" Lime Treated	8.0" Lime Treated
Subgrade	75" Silt (ML)			75" Clay (CH)		
Bedrock	-			-		

* - The version of the M-E Design Guide used in this part of the analysis (0.502) does not include a specific designation for lime treated soil. Equivalent variables were entered.

With the above layer types and thicknesses, an input file was created for each situation. Tables 2-2 through 2-18 list the data for each case. If no value is given for the minimum (Min) or maximum (Max), the variable was not changed. Sometimes this was done because the variable would have no impact (traffic direction) or because changing that variable would have an unnecessary impact (design life). When the value of the variable depends upon whether the pavement was thin, intermediate, or thick (as in the average annual daily truck traffic [AADTT]), values are listed in that order, separated by a "/."

2.1.2.1 General Variables, Table 2-2

The design life, construction dates, length of time between operations, and initial IRI are all based on typical values for asphalt concrete pavements. The functional class was varied from primary arterial (PA) to minor arterial (MA) to local road (LR), to ensure a range of values. The highest value (PA) was used as the default because it was expected that the M-E Design Guide would most likely be used on the highest volume routes.

Table 2-2. General Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Asphalt Concrete Pavements.

General Information	All Designs		
	Base	Min	Max
Design Life (years)	20	-	-
Base/SG Construction Month	March	January	May
Pavement Construction Month	June	Jan-Oct	Aug
Traffic Open Month	+2 Months	+1 Month	+ 6 Months
Functional Class	PA	MA	LR
Traffic Direction	E	-	-
Initial IRI	63	50	75

2.1.2.2 Traffic Variables, Table 2-3

For the traffic variables, the average annual daily truck traffic was based on the actual values of average annual daily traffic (AADT), percent trucks, and equivalent single axle loads that were used in the FPS19W pavement layer thickness determination.

While not normally inputs that a pavement designer would consider, the lane width, wander, wheel location, and tire pressures were included in the experiment design to illustrate the impacts of these variables.

Table 2-3. Traffic Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Asphalt Concrete Pavements.

Traffic	All Designs		
	Base	Min	Max
2-Way AADTT (Thin, Intermediate, Thick) (850 AADT, 10.7% Trucks, 390,000 ESAL)/ (9200 AADT, 12.6% Trucks, 4,130,000 ESAL)/ (7500 AADT, 27.3% Trucks, 37,242,000 ESAL)	91 1159 2047	73 966 1706	109 1391 2457
Number of Lanes	2/2/3	-	-
Percent of Trucks in Design Direction	100	-	-
Percent of Trucks in Design Lane	95/95/90	-	-
Operational Speed	60	-	-
Traffic Growth Percent (Compound)	1.83 1.67 3.72	-	-
General Traffic Inputs			
Mean Wheel Location (in. from marking)	18	14	22
Traffic Wander (SDev in.)	10	8	12
Design Lane Width (ft)	12	10	14
Tire Pressure Single (psi)	120	80	150
Tire Pressure Dual (psi)	120	80	150

2.1.2.3 Climate Variables, Table 2-4

The latitude and longitude were chosen to be between Amarillo and Lubbock for the Dry-Cold location and between Houston and Beaumont for the Wet-Warm location. Two weather stations were chosen to represent each of these pavements. The minimum and maximum values for latitude and longitude were chosen to represent the maximum deviation that could be achieved while maintaining those same two stations. Larger variation would remove a station from the list of nearby stations. The elevations and depth to water table were selected as representative of the areas. The program default value for the surface shortwave absorptivity was taken as the base value, while the variation was taken from a Purdue University lecture on meteorology (http://www.eas.purdue.edu/atms535/lecture4/lecture4.html).

Table 2-4. Climate Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Asphalt Concrete Pavements.

Environment/Climate	Dry-Cold			Wet-Warm		
	Base	Min	Max	Base	Min	Max
Latitude	34	33.2	35	29.4	28.3	30
Longitude	101.5	100.5	102.5	93.8	93	94.5
Elevation (ft)	3500	2000	5000	20	2	50
Depth of Water Table (ft)	50	1	100	20	1	50
Surface Shortwave Absorptivity	0.85	0.80	0.90	0.85	0.80	0.90

2.1.2.4 Thermal Cracking Variables, Table 2-5

Program defaults, based on the type and grade of asphalt selected were used for the base values, while the ranges were based on reasonable values. The variation for the coefficient of contraction was taken from the Federal Highway Administration website: www.tfhrc.gov/pavement/pccp/thermal.htm.

2.1.2.5 Asphalt Concrete Binder Variables, Table 2-6

Data for the base values were based on recent testing at the Texas Transportation Institute (TTI) for TxDOT Project 0-4203 “Strategic Study for Resolving Hot Mix Asphalt Related Issues.” Testing was only partially completed at the time the data were needed for this study, so only the values available at that time were used. Much of the base data and ranges for conventional binder tests were taken from standard specifications.

2.1.2.6 Asphalt Concrete General Variables, Table 2-7

Data for the base values and ranges were based on typical values for pavements in Texas. Thermal conductivity and heat capacity were taken from Johnston et al. 1981a and Johnston et al. 1981b.

Table 2-5. Thermal Cracking Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Asphalt Concrete Pavements.

	All Designs		
Thermal Cracking	Base	Min	Max
Average Tensile Strength at 14F (psi)	421/332	350/250	500/400
Creep Test Duration (sec)	100	-	-
Creep Compliance (1/psi) (Levels 1 and 2)			
2 - Creep Compl@14F for Load Time 1 sec	Default based on AC	/2	×5
2 - Creep Compl@14F for Load Time 2 sec	Default based on AC	/2	×5
2 - Creep Compl@14F for Load Time 5 sec	Default based on AC	/2	×5
2 - Creep Compl@14F for Load Time 10 sec	Default based on AC	/2	×5
2 - Creep Compl@14F for Load Time 20 sec	Default based on AC	/2	×5
2 - Creep Compl@14F for Load Time 50 sec	Default based on AC	/2	×5
2 - Creep Compl@14F for Load Time 100 sec	Default based on AC	/2	×5
1 - Creep Compl@-4F for Load Time 1 sec	Default based on AC	/2	×5
1 - Creep Compl@-4F for Load Time 2 sec	Default based on AC	/2	×5
1 - Creep Compl@-4F for Load Time 5 sec	Default based on AC	/2	×5
1 - Creep Compl@-4F for Load Time 10 sec	Default based on AC	/2	×5
1 - Creep Compl@-4F for Load Time 20 sec	Default based on AC	/2	×5
1 - Creep Compl@-4F for Load Time 50 sec	Default based on AC	/2	×5
1 - Creep Compl@-4F for Load Time 100 sec	Default based on AC	/2	×5
1 - Creep Compl@14F for Load Time 1 sec	Default based on AC	/2	×5
1 - Creep Compl@14F for Load Time 2 sec	Default based on AC	/2	×5
1 - Creep Compl@14F for Load Time 5 sec	Default based on AC	/2	×5
1 - Creep Compl@14F for Load Time 10 sec	Default based on AC	/2	×5
1 - Creep Compl@14F for Load Time 20 sec	Default based on AC	/2	×5
1 - Creep Compl@14F for Load Time 50 sec	Default based on AC	/2	×5
1 - Creep Compl@14F for Load Time 100 sec	Default based on AC	/2	×5
1 - Creep Compl@32F for Load Time 1 sec	Default based on AC	/2	×5
1 - Creep Compl@32F for Load Time 2 sec	Default based on AC	/2	×5
1 - Creep Compl@32F for Load Time 5 sec	Default based on AC	/2	×5
1 - Creep Compl@32F for Load Time 10 sec	Default based on AC	/2	×5
1 - Creep Compl@32F for Load Time 20 sec	Default based on AC	/2	×5
1 - Creep Compl@32F for Load Time 50 sec	Default based on AC	/2	×5
1 - Creep Compl@32F for Load Time 100 sec	Default based on AC	/2	×5
Compute Mix Coefficient of Contraction	1.3×10^{-5}	1.3×10^{-6}	1.3×10^{-4}
Mixture VMA	15.7	14	17.4
Aggregate Coefficient of Contraction	5.0×10^{-6}	3.0×10^{-6}	7.0×10^{-6}

Table 2-6. Asphalt Concrete Binder Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Asphalt Concrete Pavements.

Asphalt Concrete Binder	Base	Min	Max
1st AC Layer Thickness (in.) -Thin	1.5	1.0	2.0, 3.0
Intermediate	8.5	7.0	10.0
Thick	4.0	3.0	5.0
2nd AC Layer Thickness (in.) -Thick	14.0	13.0	15.0
1st AC Layer Superpave Binder -Thin (DC/WW)	64-28/76-22	58-34/64-22	76-22/82-28
Intermediate	64-28/76-22	58-34/64-22	76-22/82-28
Thick	64-28/76-22	58-34/64-22	76-22/82-28
2nd AC Layer Superpave Binder -Thick	76-22/76-22	70-28/70-22	82-16/82-22
1st AC Layer Conventional Binder -Thin (DC/WW)	10/20	5/10	20/30
Intermediate	10/20	5/10	20/30
Thick	10/30	5/20	20/40
2nd AC Layer Conventional Binder -Thick	30/20	20/30	40/40
Level 1-40F G*-Delta (DC/WW)	4939692-50.9 5743308-43.8	Base/3	Base×3
Level 1-70F G*-Delta (DC/WW)	259317-64.9 494183-57.1	Base/3	Base×3
Level 1-100F G*-Delta (DC/WW)	41885-72.8 96380-65.2	Base/3	Base×3
Level 1-Softening Pt @ 0F (DC/WW) 1st Layer	130 /170	120/160	140/180
Level 1-Softening Pt @ 0F (DC/WW) 2nd Layer	170 /170	160/160	180/180
Level 1-Absolute Visc @140F(DC/WW) 1st Layer	1000/2000	800/1600	1200/2400
Level 1-Absolute Visc @140F(DC/WW) 2nd Layer	2000/2000	1600/1600	2400/2400
Level 1-Kinematic Visc @275F (DC/WW) 1st Layer	275/325	250/300	325/350
Level 1-Kinematic Visc @275F (DC/WW) 2nd Layer	325/325	300/300	350/350
Level 1-Specific Gravity @77F (DC/WW) 1st Layer	1.04	1.02	1.06
Level 1-Penetration@77F (DC/WW) 1st Layer	80/60	70/55	110/70
Level 1-Penetration@77F (DC/WW) 2nd Layer	60/60	55/55	70/70
Level 1-Brookfield Visc@275F (DC/WW)	3	Base×0.83	Base×1.17
@175F (DC/WW)	100		
@355F (DC/WW)	0.5		
@94F (DC/WW)	2840000/948000		
@134F (DC/WW)	24800/8280		
@210F (DC/WW)	563/106		

Table 2-7. Asphalt Concrete General Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Asphalt Concrete Pavements.

Asphalt General	Base	Min	Max
Reference Temperature (°F)	70	65	75
Effective Binder Content (% by Vol.)(DC/WW)	11	8	14
Air Voids (%)(DC/WW)	4.7	3.0	8.5
Total Unit Wt (pcf)(DC/WW)	148	142	154
Poisson's Ratio	0.35	0.30	0.40
Thermal Conductivity (BTU/hr-ft-°F)	0.67	0.53	0.81
Heat Capacity (BTU/lb-°F)	0.23	0.31	0.40

2.1.2.7 Asphalt Concrete Mix Variables, Table 2-8

Data for the base values and ranges were based on TxDOT Specification 346. The dynamic modulus was taken from recent testing at TTI for TxDOT Project 0-4203 "Strategic Study for Resolving Hot Mix Asphalt Related Issues." Testing was only partially completed at the time the data were needed for this project, so only the values available at that time were used.

Table 2-9 contains the dynamic modulus data used in the analysis. The values used depended on the grade of binder used in the mix.

Table 2-8. Asphalt Concrete Mix Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Asphalt Concrete Pavements.

Asphalt Concrete Mix	Mid	Min	Max
Level 3,2-Cum % Retained 3/4"(DC/WW)	10	0	20
Level 3,2-Cum % Retained 3/8"(DC/WW)	20	10	30
Level 3,2-Cum % Retained #4 (DC/WW)	30	20	40
Level 3,2-% Pass #200 (DC/WW)	6	4	8
Level 1-Dynamic Modulus (based on grade of asphalt)	Mid	Base/1.5	Base×1.5

2.1.2.8 Crushed Stone Strength Variables, Table 2-10

Data for the base values and ranges were based on TxDOT Specification 247 and the learned opinions of TxDOT personnel. The coefficient of lateral pressure value used was the program default.

Table 2-9. Asphalt Concrete Dynamic Modulus Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Asphalt Concrete Pavements.

Temperature and Frequency	PG 64-22	PG 58-34	PG 76-22
10 °F@ 0.1	2202656	2088331	1449100
@ 1.0	2839600	2809743	1682650
@ 10	3445013	3528018	1925375
@ 25	3668700	3831800	2008800
40 °F@ 0.1	988269	672295	814000
@ 1.0	1516654	1168968	1115350
@ 10	2117063	1802423	1405600
@ 25	2391693	2099089	1556600
70 °F@ 0.1	261901	151121	253800
@ 1.0	501168	287222	464575
@ 10	917925	571935	789850
@ 25	1108645	751858	947750
100 °F@ 0.1	59869	41770	80125
@ 1.0	107049	69612	137558
@ 10	223674	133464	259803
@ 25	310107	180150	338200
130 °F@ 0.1	30553	43415	44010
@ 1.0	44966	33626	69335
@ 10	78091	85720	115930
@ 25	104293	105147	145210

Table 2-10. Crushed Stone Strength Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Asphalt Concrete Pavements.

Crushed Stone Strength (DC/WW)	Base	Min	Max
Thickness (in.)	6.0/8.0	5.0/7.0	7.0/9.0
Level 3 - Poisson's Ratio	0.35	0.30	0.40
Level 3 - Coefficient of Lateral Pressure K_o	0.50	0.40	0.60
Level 3 - Modulus (ksi)	50	25	100

2.1.2.9 Crushed Stone ICM Variables, Table 2-11

Data for the base values and ranges were based on TxDOT Specification 247, the opinions of current and former TxDOT personnel, and program defaults. The saturated hydraulic conductivity was taken from the website:
http://instaar.colorado.edu/deltaforce/models/hydrotrend/ko_table.html

The soil water characteristic curve was taken from Fredlund and Xing (1994).

Table 2-11. Crushed Stone ICM Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Asphalt Concrete Pavements.

Crushed Stone ICM	Base	Min	Max
Level 3 - ICM Inputs or Representative Value	I	-	R
Level 3 - Plasticity Index	7	4	10
Level 3 - Passing #200 (%)	7	4	10
Level 3 - Passing #4 (%)	40	35	55
Level 3 - D60 (mm)	4.0	3.3	4.7
Level 3 - Maximum Dry Unit Wt (pcf)	121	115	128
Level 3 - Specific Gravity of Solids	2.68	2.62	2.74
Level 3 - Saturated Hydraulic Conductivity (ft/hr)	1200	500	1800
Level 3 - Optimum Gravimetric Water Content (%)	11.8	10.0	14.0
Level 3 - Soil Water Characteristic Curve			
af	19	1.8	190
bf	4.1	4.5	3.7
cf	1.2	1.16	1.3
Hr	3000	3000	5000
Level 3 - Compacted or Uncompacted	C	U	-
Level 2 - Seasonal Values (Vary up and down by 2k)	Y	-	-

2.1.2.10 Lime Treated Strength Variables, Table 2-12

The version of the M-E Design Guide used in this part of the analysis (0.502) does not include a designation for lime treated soil. Therefore, best estimates for the base values and ranges were provided by TTI and TxDOT personnel.

Table 2-12. Lime Treated Strength Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Asphalt Concrete Pavements.

Lime Treated CH Soil Strength	Base	Min	Max
Thickness (in.)	8.0	6.0	10.0
Level 3 - Poisson's Ratio	0.30	0.15	0.40
Level 3 - Coefficient of Lateral Pressure Ko	0.50	0.40	0.60
Level 3 - Modulus (ksi)	35	25	45

2.1.2.11 Lime Treated ICM Variables, Table 2-13

The version of the M-E Design Guide used in this part of the analysis (0.502) does not include a designation for lime treated soil. Therefore, best estimates for the base values and ranges were provided by TTI and TxDOT personnel. The saturated hydraulic conductivity was estimated from Freeze and Cherry (1979), and the soil water characteristic curve was taken from Fredlund and Xing (1994).

Table 2-13. Lime Treated ICM Strength Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Asphalt Concrete Pavements.

Lime Treated CH Soil ICM	Base	Min	Max
Level 3 - ICM Inputs or Representative Value	I	-	R
Level 3 - Plasticity Index	2	0	6
Level 3 - Passing #200 (%)	10	0	20, 80
Level 3 - Passing #4 (%)	95	85	100
Level 3 - D60 (mm)	2.0	0.5	4.0
Level 3 - Maximum Dry Unit Wt (pcf)	122	110	130
Level 3 - Specific Gravity of Solids	2.68	2.62	2.74
Level 3 - Saturated Hydraulic Conductivity (ft/hr)	37	10	55
Level 3 - Optimum Gravimetric Water Content (%)	11.2	8.0	14.0
Level 3 - Soil Water Characteristic Curve			
af	19	1.95	15150
bf	4.1	2.7	1.1
cf	1.2	1.08	0.865
Hr	3000	3000	5000
Level 3 - Compacted or Uncompacted	C	U	-
Level 2 - Seasonal Values (Vary up and down by 2k)	Y	-	-

2.1.2.12 Dry-Cold Subgrade (ML) Strength Variables, Table 2-14

The thickness and modulus of the subgrade were estimated values from TxDOT and TTI personnel. Program default values were used for the other base values.

Table 2-14. Dry-Cold Subgrade (ML) Strength Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Asphalt Concrete Pavements.

Subgrade (ML) Strength	Dry-Cold		
	Mid	Min	Max
Thickness (in.)	75	50	100
Level 3 - Poisson's Ratio	0.35	0.30	0.40
Level 3 - Coefficient of Lateral Pressure Ko	0.50	0.40	0.60
Level 3 - Modulus (ksi)	12	7	17

2.1.2.13 Dry-Cold Subgrade (ML) ICM Variables, Table 2-15

The best estimates for the base values and ranges were provided by TTI and TxDOT personnel. Program default values were used for the other base values. The saturated hydraulic conductivity was estimated from Freeze and Cherry (1979), and the soil water characteristic curve was taken from Fredlund and Xing (1994).

Table 2-15. Dry-Cold Subgrade (ML) ICM Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Asphalt Concrete Pavements.

Subgrade (ML) ICM	Dry-Cold		
	Mid	Min	Max
Level 3 - ICM Inputs or Representative Value	I	-	R
Level 3 - Plasticity Index	10	5	15
Level 3 - Passing #200 (%)	80	70	90
Level 3 - Passing #4 (%)	95	-	-
Level 3 - D60 (mm)	.05	.02	.08
Level 3 - Maximum Dry Unit Wt (pcf)	111.2	90	130
Level 3 - Specific Gravity of Solids	2.72	2.67	2.78
Level 3 - Saturated Hydraulic Conductivity (ft/hr)	6.23×10^{-6}	1.0×10^{-7}	4.0×10^{-4}
Level 3 - Optimum Gravimetric Water Content (%)	16.9	15	19
Level 3 - Soil Water Characteristic Curve			
af	46.9	30	60
bf	1.21	1.00	1.50
cf	.635	.50	1.00
Hr	1.76×10^{-3}	1.0×10^{-2}	1.0×10^{-4}
Level 3 - Compacted or Uncompacted	C	U	-
Level 2 - Seasonal Values (Vary up and down by 2k)	Y	Y	Y

2.1.2.14 Wet-Warm Subgrade (CH) Strength Variables, Table 2-16

The thickness and modulus of the subgrade were estimated values from TxDOT and TTI personnel. Program default values were used for the other base values.

Table 2-16. Wet-Warm Subgrade (CH) Strength Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Asphalt Concrete Pavements.

Subgrade (CH) Strength	Wet-Warm		
	Mid	Min	Max
Thickness (in.)	75	50	100
Level 3 - Poisson's Ratio	0.35	0.30	0.40
Level 3 - Coefficient of Lateral Pressure Ko	0.50	0.40	0.60
Level 3 - Modulus (ksi)	8	6	12

2.1.2.15. Wet-Warm Subgrade (CH) ICM Variables, Table 2-17

The best estimates for the base values and ranges were provided by TTI and TxDOT personnel. Program default values were used for the other base values. The saturated hydraulic conductivity was estimated from Freeze and Cherry (1979), and the soil water characteristic curve was taken from Fredlund and Xing (1994).

2.1.2.16 Bedrock Variables, Table 2-18

The best estimates for the base values and ranges were provided by TTI and TxDOT personnel.

Table 2-17. Wet-Warm Subgrade (CH) ICM Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Asphalt Concrete Pavements.

Subgrade (CH) ICM	Wet-Warm		
	Mid	Min	Max
Thickness (in.)	75	50	100
Level 3 - Poisson's Ratio	0.35	0.30	0.40
Level 3 - Coefficient of Lateral Pressure Ko	0.50	0.40	0.60
Level 3 - Modulus (ksi)	8	6	12
Level 3 - ICM Inputs or Representative Value	I	I	R
Level 3 - Plasticity Index	35	25	45
Level 3 - Passing #200 (%)	75	65	85
Level 3 - Passing #4 (%)	95	-	-
Level 3 - D60 (mm)	0.01	0.003	0.02
Level 3 - Maximum Dry Unit Wt (pcf)	96.7	80	120
Level 3 - Specific Gravity of Solids	2.76	2.66	2.86
Level 3 - Saturated Hydraulic Conductivity (ft/hr)	2.2×10^{-7}	1.0×10^{-8}	1.0×10^{-6}
Level 3 - Optimum Gravimetric Water Content (%)	25.1	15	35
Level 3 - Soil Water Characteristic Curve			
af	323	200	450
bf	0.989	0.8	1.1
cf	0.735	0.60	0.85
Hr	1.7×10^{-4}	1.0×10^{-3}	1.0×10^{-5}
Level 3 - Compacted or Uncompacted	C	U	-
Level 2 - Seasonal Values (Vary up and down by 2k)	Y	Y	Y

Table 2-18. Bedrock Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Asphalt Concrete Pavements.

Bedrock	All Designs		
	Mid	Min	Max
Massive and Continuous or Fractured	M	F	
Unit Weight (pcf)	120	100	140
Poisson's Ratio	0.35	0.30	0.40
Resilient Modulus (ksi)	1000	800	1200

Appendices C and D contain the results of the sensitivity analysis for the Dry-Cold and Wet-Warm, AC-Thin runs. Appendices E and F contain the results of the sensitivity analysis for the Dry-Cold and Wet-Warm, AC-Intermediate runs. Appendices G and H contain the results of the sensitivity analysis for the Dry-Cold and Wet-Warm AC-Thick runs.

2.1.3 Continuously Reinforced Concrete Pavements (CRCP)

Typically, continuously reinforced pavements are used in situations where the truck traffic is high. For this project, a typical high volume truck traffic design in each climatic area was analyzed. In the Dry-Cold region, the pavement design includes the CRCP layer with a 4 inch AC subbase layer to provide a nonerodible, structural base layer, provide a working platform, and act as a bond breaker. Below that is the lime treated layer and then the subgrade. In the Wet-Warm areas, a 1-inch bond breaker and a 6-inch cement stabilized subbase are used. Table 2-19 lists the material types and thickness used in the evaluation of the M-E Design Guide.

Table 2-19. Layer Types and Thicknesses Used in M-E Pavement Design Guide Sensitivity Analysis of Continuously Reinforced Concrete Pavements.

Layers	Dry-Cold	Wet-Warm
CRCP Surface	13.0"	13.0
AC Layer	4.0" HMAC	1.0" HMAC
Cement Stabilized Base		6.0" Cement Stabilized
*Treated Layer	8.0" Lime Treated	8.0" Lime Treated
Subgrade	100" Silt (ML)	100" Clay (CH)
Bedrock	-	-

* - The version of the M-E Design Guide used in this part of the analysis (0.502) does not include a specific designation for lime treated soil. Equivalent variables were entered.

With the above layer types and thicknesses, an input file was created for each situation. The tables below list the data for each case. If no value is given for the minimum (Min) or maximum (Max), the variable was not changed. Sometimes this was done because the variable would have no impact (traffic direction) or because changing that variable would have an unnecessary impact (design life).

2.1.3.1 General Variables, Table 2-20

The design life, construction dates, and length of time between operations are all based on typical values for CRC pavements. The functional class was varied from primary arterial (PA) to minor arterial (MA) to local road (LR), to ensure a range of values. The highest value (PA) was used as the default because it was expected that the M-E Design Guide would most likely be used on the highest volume routes.

Table 2-20. General Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Continuously Reinforced Concrete Pavements.

General Information	Dry-Cold CRC/4"AC			Wet-Warm CRC/1"AC/CTB		
	Mid	Min	Max	Mid	Min	Max
Design Life (years)	30	-	-	30	-	-
Pavement Construction Month	June	Jan-Oct	Aug	June	Jan-Oct	Aug
Traffic Open Month	+2 Months	+1 Month	+ 6 Months	+ 2 Months	+1 Month	+ 6 Months
Functional Class	PA	MA	LR	PA	MA	LR
Traffic Direction	E			E		

2.1.3.2 Traffic Variables, Table 2-21

For the traffic variables, the average annual daily truck traffic was based on the approximate values of average annual daily traffic, percent trucks, and equivalent single axle loads for a heavily trafficked pavement.

While not normally inputs that a pavement designer would consider, the lane width, wander, wheel location, and tire pressures were included in the experiment design to illustrate the impacts of these variables.

2.1.3.3 Climate Variables, Table 2-22

The latitude and longitude were chosen to be between Amarillo and Lubbock for the Dry-Cold location and between Houston and Beaumont for the Wet-Warm location. Two weather stations were chosen to represent each of these pavements. The minimum and maximum values for latitude and longitude were chosen to represent the maximum deviation that could be achieved while maintaining those same two stations. Larger variation would remove a station from the list of nearby stations. The elevations and depth to water table were selected as representative of the areas.

Table 2-21. Traffic Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Continuously Reinforced Concrete Pavements.

Traffic	Dry-Cold CRC/4"AC			Wet-Warm CRC/1"AC/CTB		
	Mid	Min	Max	Mid	Min	Max
Two Way AADTT (40000 AADT, 20% Trucks)	8000	6400	9600	8000	6400	9600
Number of Lanes	2	-	-	2	-	-
Percent of Trucks in Design Direction	50	-	-	50	-	-
Percent of Trucks in Design Lane	95	-	-	95	-	-
Operational Speed	60	-	-	60	-	-
Traffic Growth Percent (Compound)	4	-	-	4	-	-
General Traffic Inputs						
Mean Wheel Location (in. from marking)	18	14	22	18	14	22
Traffic Wander (Sdev in.)	10	8	12	10	8	12
Design Lane Width (ft)	12	10	14	12	10	14
Tire Pressure Single (psi)	120	80	150	120	80	150
Tire Pressure Dual (psi)	120	80	150	120	80	150

Table 2-22. Climate Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Continuously Reinforced Concrete Pavements.

Environment/Climate	Dry-Cold CRC/4"AC			Wet-Warm CRC/1"AC/CTB		
	Mid	Min	Max	Mid	Min	Max
Latitude	34	33.2	35	29.4	28.3	30
Longitude	101.5	100.5	102.5	93.8	93	94.5
Elevation (ft)	3500	2000	5000	20	2	50
Depth of Water Table (ft)	50	1	100	20	1	50

2.1.3.4 CRCP Design Feature Variables, Table 2-23

The shoulder type that was chosen is the best type available, and what is normally used in TxDOT. The default curl/warp temperature was used and the ranges were provided by TTI. The steel parameters and crack spacing were provided by TxDOT, while the default program values were used for the variables concerning the base.

Table 2-23. CRCP Design Feature Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Continuously Reinforced Concrete Pavements.

CRCP Design Features	Dry-Cold CRC/4"AC			Wet-Warm CRC/1"AC/CTB		
	Mid	Min	Max	Mid	Min	Max
Shoulder Type	Tied	AC	-	Tied	AC	-
Permanent Curl/Warp Temp Diff (°F)	-10	-6	-15	-10	-6	-15
Steel Reinforcement (%)	0.6	0.4	0.8	0.6	0.4	0.8
Bar Diameter (in.)	0.625	0.500	0.750	0.625	0.500	0.750
Steel Depth (in.)	½ T	¼ T	-	½ T	¼ T	-
Base Erodibility Index (1-5)	3	4	1	3	4	1
Base/Slab Friction Coefficient	7.1	3.7	10	7.1	3.7	10
Generate cracking spacing using model	Y	-	-	Y	-	-
Enter Mean Crack Spacing (in.)	48	30	72	48	30	72

2.1.3.5 Drainage and Surface Property Variables, Table 2-24

The program default value for the surface shortwave absorptivity was taken as the base value, while the variation was taken from a Purdue University lecture on meteorology: http://www.eas.purdue.edu/atms535/lecture4/lecture4.html

The other variables were program defaults and reasonable ranges.

Table 2-24. Drainage and Surface Property Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Continuously Reinforced Concrete Pavements.

Drainage and Surface Properties	Dry-Cold CRC/4"AC			Wet-Warm CRC/1"AC/CTB		
	Mid	Min	Max	Mid	Min	Max
Surface Shortwave Absorptivity	0.85	0.80	0.90	0.85	0.80	0.90
Infiltration	Min	Mod	Neg	Mod	Ext	Min
Drainage Path Length (ft)	12	10	15	12	10	15
Pavement Cross Slope (%)	2	0	4	2	0	4

2.1.3.6 CRCP Mix Design Variables, Table 2-25

The cement content and water/cement (w/c) ratio were provided by TxDOT. Other values and ranges were program defaults and best estimates of TTI personnel. CC is curing compound.

Table 2-25. CRCP Mix Design Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Continuously Reinforced Concrete Pavements.

CRCP Mix Design	Dry-Cold CRC/4"AC			Wet-Warm CRC/1"AC/CTB		
	Mid	Min	Max	Mid	Min	Max
Cement Type	I	-	-	I	-	-
Cement Content (lb/yd^3)	517	470	564	517	470	564
Water/Cement Ratio	0.45	0.48	0.42	0.45	0.48	0.42
Aggregate Type	Lime	Chert/Grav	Basalt	Lime	Chert/Grav	Basalt
PCC Zero-stress Temp (°F)	107	90	130	107	90	130
Reversible Shrinkage (% Ultimate)	50	25	75	50	25	75
Days to Develop 50% Ultimate Shrink	45	30	60	45	30	60
Curing Method	CC		Wet	CC		Wet

2.1.3.7 CRCP Strength Variables, Table 2-26

The 28-day strengths were provided by TxDOT, while the strength data for other times were provided by TTI.

2.1.3.8 CRCP Thermal Variables, Table 2-27

The unit weight and Poisson's ratio were provided by TxDOT, the thermal contraction came from experts at TTI, while the thermal conductivity and heat capacity were taken from Johnston et al. 1981a and Johnston et al. 1981b.

Table 2-26. CRCP Strength Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Continuously Reinforced Concrete Pavements.

CRCP Strength	Dry-Cold CRC/4"AC			Wet-Warm CRC/1"AC/CTB		
	Mid	Min	Max	Mid	Min	Max
Level 3, 28 day Mod of Rupture (psi)	620	580	670	620	580	670
Level 3, 28 day Compr. Strength (psi)	4000	3200	5000	4000	3200	5000
Level 2, 7 day Compr. Strength (psi)	1500	1300	1800	1500	1300	1800
Level 2, 14 day Compr. Strength (psi)	2000	1750	2500	2000	1750	2500
Level 2, 28 day Compr. Strength (psi)	4000	3200	5000	4000	3200	5000
Level 2, 90 day Compr. Strength (psi)	4500	3500	5500	4500	3500	5500
20 Yr/28 day Compressive Strength	1.35	1.2	1.5	1.35	1.2	1.5
Level 1, 7 day Compr. Strength (psi)	1500	1300	1800	1500	1300	1800
Level 1, 14 day Compr. Strength (psi)	2000	1750	2500	2000	1750	2500
Level 1, 28 day Compr. Strength (psi)	4000	3200	5000	4000	3200	5000
Level 1, 90 day Compr. Strength (psi)	4500	3500	5500	4500	3500	5500
20 Yr/28 day Compressive Strength	1.35	1.2	1.5	1.35	1.2	1.5
Level 1, 7 day E (ksi)	2000	1300	2300	2000	1800	2300
Level 1, 14 day E (ksi)	2900	1750	3400	2900	2600	3400
Level 1, 28 day E (ksi)	3500	3200	4000	3500	3000	4000
Level 1, 90 day E (ksi)	4000	3500	4500	4000	3500	4500
20 Yr/28 day E	1.35	1.2	1.5	1.35	1.2	1.5
Level 1, 7 day Mr (psi)	300	250	350	300	250	350
Level 1, 14 day Mr (psi)	500	450	550	500	450	550
Level 1, 28 day Mr (psi)	620	580	670	620	580	670
Level 1, 90 day Mr (psi)	650	600	750	650	600	750
20 Yr/28 day Mr	1.35	1.2	1.5	1.35	1.2	1.5

Table 2-27. CRCP Thermal Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Continuously Reinforced Concrete Pavements.

CRCP Thermal Properties	Dry-Cold CRC/4"AC			Wet-Warm CRC/1"AC/CTB		
	Mid	Min	Max	Mid	Min	Max
Thickness (in.)	13	11	15	13	11	15
Unit Weight (pcf)	145	140	150	145	140	150
Poisson's Ratio	0.15	0.10	0.20	0.15	0.10	0.20
Coeff. of Thermal Contract ($^{o}F\times10^{-6}$)	6	4	9	6	4	9
Ultimate Shrink @40% RH (Microstrain)	643	500	800	643	500	800
Thermal Conductivity (BTU/hr-ft-°F)	1.5	1.4	1.7	1.5	1.4	1.7
Heat Capacity (BTU/lb-°F)	0.28	0.25	0.30	0.28	0.25	0.30

2.1.3.9 AC Layer Binder Property Variables, Table 2-28

Typical AC binder types were identified. While listed as a base value, the options provided by the program are for either PG or conventionally graded binders. Therefore, the conventional binders were compared to the base value for the Superpave binders. Only Level 3 data were entered for any of the HMAC layers.

Table 2-28. AC Layer Binder Property Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Continuously Reinforced Concrete Pavements.

AC Layer Binder Properties	Dry-Cold CRC/4"AC			Wet-Warm CRC/1"AC/CTB		
	Mid	Min	Max	Mid	Min	Max
Superpave Binder	64-28	58-22	70-34	70-22	64-16	76-28
Conventional Viscosity Grade	10	5	20	20	10	30

2.1.3.10 AC Layer General Property Variables, Table 2-29

Typical AC layer properties were entered, with the thermal conductivity and heat capacity taken from Johnston et al. 1981a and Johnston et al. 1981b.

Table 2-29. AC Layer General Property Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Continuously Reinforced Concrete Pavements.

AC Layer General Properties	Dry-Cold CRC/4"AC			Wet-Warm CRC/1"AC/CTB		
	Mid	Min	Max	Mid	Min	Max
Reference Temperature (°F)	70	65	75	70	65	75
Effective Binder Content (% by Vol.)	11	8	14	11	8	14
Air Voids (%)	8.5	6.5	11	8.5	6.5	11
Total Unit Wt (pcf)	148	142	154	148	142	154
Poisson's Ratio	0.35	0.30	0.40	0.35	0.30	0.40
Thermal Conductivity (BTU/hr-ft-°F)	0.67	0.53	0.81	0.67	0.53	0.81
Heat Capacity (BTU/lb-°F)	0.23	0.30	0.40	0.23	0.30	0.40

2.1.3.11 AC Layer Mix Variables, Table 2-30

Typical AC layer gradations were entered.

Table 2-30. AC Layer Mix Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Continuously Reinforced Concrete Pavements.

AC Layer Mix	Dry-Cold CRC/4"AC			Wet-Warm CRC/1"AC/CTB		
	Mid	Min	Max	Mid	Min	Max
Thickness (in.)	4	3	5	1	1	2
Cum % Retained 3/4"	10	0	20	10	0	20
Cum % Retained 3/8"	20	10	30	20	10	30
Cum % Retained #4	30	20	40	30	20	40
% Pass #200	6	4	8	6	4	8

2.1.3.12 Cement Stabilized Layer ICM Variables, Table 2-31

The CRC pavements were analyzed with an early version of the M-E Design Guide (version 0.088). At that time, stabilized layers were considered in much the same way as other base layers and had similar inputs. The following inputs reflect that earlier data entry. More recent versions consider stabilized layers as being fairly strong with a high elastic modulus and a modulus of rupture.

Table 2-31. Cement Stabilized Layer ICM Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Continuously Reinforced Concrete Pavements.

Cement Stabilized Layer ICM	Dry-Cold CRC/4"AC			Wet-Warm CRC/1"AC/CTB		
	Mid	Min	Max	Mid	Min	Max
Unit Weight (pcf)	-	-	-	150	140	160
Thermal Conductivity (BTU/hr-ft-ºF)	-	-	-	1.25	1.15	1.35
Heat Capacity (BTU/lb-ºF)	-	-	-	0.28	0.25	0.31

2.1.3.13 Cement Stabilized Layer Strength Variables, Table 2-32

Best estimates of typical values were entered.

Table 2-32. Cement Stabilized Layer Strength Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Continuously Reinforced Concrete Pavements.

Cement Stabilized Layer Strength	Dry-Cold CRC/4"AC			Wet-Warm CRC/1"AC/CTB		
	Mid	Min	Max	Mid	Min	Max
Thickness (in.)				6	5	7
Poisson's Ratio	-	-	-	0.2	0.15	0.3
Resilient Modulus (ksi)	-	-	-	1000	500	2000

2.1.3.14 Lime Treated Strength Variables, Table 2-33

The version of the M-E Design Guide used in this part of the analysis (0.088) does not include a designation for lime treated soil. Therefore, best estimates for the base values and ranges were provided by TTI and TxDOT personnel.

Table 2-33. Lime Treated Strength Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Continuously Reinforced Concrete Pavements.

Lime Treated Strength	Dry-Cold CRC/4"AC			Wet-Warm CRC/1"AC/CTB		
	Mid	Min	Max	Mid	Min	Max
Thickness (in.)	8	6	10	8	6	10
Poisson's Ratio	0.2	0.15	0.3	0.2	0.15	0.3
Resilient Modulus (ksi)	150	50	300	150	50	300

2.1.3.15 Lime Treated ICM Variables, Table 2-34

The version of the M-E Design Guide used in this part of the analysis (0.088) does not include a designation for lime treated soil. Therefore, best estimates for the base values and ranges were provided by TTI and TxDOT personnel. The saturated hydraulic conductivity was estimated from Freeze and Cherry (1979), and the soil water characteristic curve was taken from Fredlund and Xing (1994).

Table 2-34. Lime Treated ICM Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Continuously Reinforced Concrete Pavements.

Lime Treated ICM	Dry-Cold CRC/4"AC			Wet-Warm CRC/1"AC/CTB		
	Mid	Min	Max	Mid	Min	Max
Unit Weight (pcf)	150	125	175	150	125	175
Thermal Conductivity (BTU/hr-ft-°F)	1.25	1.00	1.50	1.25	1.00	1.50
Heat Capacity (BTU/lb-°F)	0.28	0.25	0.20	0.28	0.25	0.20

2.1.3.16 Dry-Cold Subgrade (ML) Strength Variables, Table 2-35

The thickness and modulus of the subgrade were estimated values from TxDOT and TTI personnel. Program default values were used for the other base values.

Table 2-35. Dry-Cold Subgrade (ML) Strength Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Continuously Reinforced Concrete Pavements.

Subgrade (ML) Strength	Dry-Cold CRC/4"AC		
	Mid	Min	Max
Thickness (in.)	100	50	150
Level 3 - Poisson's Ratio	0.35	0.30	0.40
Level 3 - Coefficient of Lateral Pressure Ko	0.50	0.40	0.60
Level 3 - Modulus (ksi)	20	10	30
Level 3 - ICM Inputs or Representative Value	I	-	R
Level 3 - Compacted or Uncompacted	C	U	-
Level 2 - Seasonal Values (Vary up and down by 2k)	Y	Y	Y

2.1.3.17 Dry-Cold Subgrade (ML) ICM Variables, Table 2-36

The best estimates for the base values and ranges were provided by TTI and TxDOT personnel. Program default values were used for the other base values. The saturated hydraulic conductivity was estimated from Freeze and Cherry (1979), and the soil water characteristic curve was taken from Fredlund and Xing (1994).

Table 2-36. Dry-Cold Subgrade (ML) ICM Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Continuously Reinforced Concrete Pavements.

Subgrade (ML) ICM	Dry-Cold CRC/4"AC		
	Mid	Min	Max
Level 3 - Plasticity Index	10	5	15
Level 3 - Passing #200 (%)	80	70	90
Level 3 - Passing #4 (%)	95	-	-
Level 3 - D60 (mm)	.05	.02	.08
Level 3 - Maximum Dry Unit Wt (pcf)	111.2	90	130
Level 3 - Specific Gravity of Solids	2.72	2.67	2.78
Level 3 - Saturated Hydraulic Conductivity (ft/hr)	6.23×10^{-6}	1×10^{-7}	4×10^{-4}
Level 3 - Optimum Gravimetric Water Content (%)	16.9	15	19
Level 3 - Soil Water Characteristic Curve			
af	46.9	30	60
bf	1.21	1.00	1.50
cf	0.635	0.50	1.00
Hr	1.76×10^{-3}	1×10^{-2}	1×10^{-4}
Level 3 - Compacted or Uncompacted	C	U	-

2.1.3.18 Wet-Warm Subgrade (CH) Strength Variables, Table 2-37

The thickness and modulus of the subgrade were estimated values from TxDOT and TTI personnel. Program default values were used for the other base values.

Table 2-37. Wet-Warm Subgrade (CH) Strength Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Continuously Reinforced Concrete Pavements.

Subgrade (CH) ICM	Wet-Warm CRC/1"AC/CTB		
	Mid	Min	Max
Thickness (in.)	100	50	150
Level 3 - Poisson's Ratio	0.35	0.30	0.40
Level 3 - Coefficient of Lateral Pressure Ko	0.50	0.40	0.60
Level 3 - Modulus (ksi)	8	5	11
Level 3 - ICM Inputs or Representative Value	I	I	R
Level 2 - Seasonal Values (Vary up and down by 2k)	Y	Y	Y

2.1.3.19 Wet-Warm Subgrade (CH) ICM Variables, Table 2-38

The best estimates for the base values and ranges were provided by TTI and TxDOT personnel. Program default values were used for the other base values. The saturated hydraulic conductivity was estimated from Freeze and Cherry (1979), and the soil water characteristic curve was taken from Fredlund and Xing (1994).

Table 2-38. Wet-Warm Subgrade (CH) ICM Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Continuously Reinforced Concrete Pavements.

Subgrade (CH) Strength	Wet-Warm CRC/1"AC/CTB		
	Mid	Min	Max
Level 3 - Plasticity Index	35	25	45
Level 3 - Passing #200 (%)	75	65	85
Level 3 - Passing #4 (%)	95	-	-
Level 3 - D60 (mm)	0.01	0.003	0.02
Level 3 - Maximum Dry Unit Wt (pcf)	96.7	80	120
Level 3 - Specific Gravity of Solids	2.76	2.66	2.86
Level 3 - Saturated Hydraulic Conductivity (ft/hr)	2.2×10^{-7}	1×10^{-8}	1×10^{-6}
Level 3 - Optimum Gravimetric Water Content (%)	25.1	15	35
Level 3 - Soil Water Characteristic Curve			
af	323	200	450
bf	0.989	0.8	1.1
cf	0.735	0.60	0.85
Hr	1.7×10^{-4}	$\times10^{-3}$	$\times10^{-5}$
Level 3 - Compacted or Uncompacted	C	U	-

2.1.3.20 Bedrock Variables, Table 2-39

The best estimates for the base values and ranges were provided by TTI and TxDOT personnel.

Table 2-39. Bedrock Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Continuously Reinforced Concrete Pavements.

Bedrock	Dry-Cold CRC/4"AC			Wet-Warm CRC/1"AC/CTB		
	Mid	Min	Max	Mid	Min	Max
Massive and Continuous or Fractured	M	F		M	F	
Unit Weight (pcf)	120	100	140	120	100	140
Poisson's Ratio	0.35	0.30	0.40	0.35	0.30	0.40
Resilient Modulus (ksi)	1000	800	1200	1000	800	1200

Appendices I and J contain the results of the sensitivity analysis for the Dry-Cold and Wet-Warm, CRCP runs.

2.1.4. Jointed Plain Concrete Pavements (JPCP)

While JPC pavements are no longer used extensively in Texas, many still exist, especially in the Wet-Warm areas and they were included in the analysis.

The pavement layers in Table 2-40 were used to evaluate the M-E Design Guide for JPC pavements.

Table 2-40. Layer Types and Thicknesses Used in M-E Pavement Design Guide Sensitivity Analysis of Jointed Concrete Pavements.

Layers	Wet-Warm
JPCP Surface	10.0"
AC Layer	1.0" HMAC
*Treated Layer	6.0" Lime Treated
Subgrade	75" Clay (CH)
Bedrock	-

* - The version of the M-E Design Guide used in this part of the analysis (0.502) does not include a specific designation for lime treated soil. Equivalent variables were entered. Currently, TxDOT uses a cement stabilized base.

With the above layer types and thicknesses, an input file was created for each situation. The tables below list the data for each case. If no value is given for the minimum (Min) or maximum (Max), the variable was not changed. Sometimes this was done because the variable would have no impact (traffic direction) or because changing that variable would have an unnecessary impact (design life).

2.1.4.1 General Variables, Table 2-41

The design life, construction dates, and length of time between operations are all based on typical values for JPCP pavements. The functional class was varied from primary arterial (PA) to minor arterial (MA) to local road (LR), to ensure a range of values. The highest value (PA) was used as the default because it was expected that the M-E Design Guide would most likely be used on the highest volume routes.

Table 2-41. General Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Jointed Plain Concrete Pavements.

General Information	Wet-Warm		
	Mid	Min	Max
Design Life (years)	30	-	-
Pavement Construction Month	June	Jan-Oct	Aug
Traffic Open Month	+2 Months	+1 Month	+ 6 Months
Functional Class	PA	MA	LR
Initial IRI	63	50	75

2.1.4.2 Traffic Variables, Table 2-42

For the traffic variables, the average annual daily truck traffic was based on the approximate values of average annual daily traffic, percent trucks, and equivalent single axle loads for a heavily trafficked pavement.

While not normally inputs that a pavement designer would consider, the lane width, wander, wheel location, and tire pressures were included in the experiment design to illustrate the impacts of these variables.

Table 2-42. Traffic Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Jointed Plain Concrete Pavements.

Traffic	Wet-Warm		
	Mid	Min	Max
Two Way AADTT (40000 AADT, 29% Trucks)	11600	9174	13910
Number of Lanes	2	-	-
Percent of Trucks in Design Direction	50	-	-
Percent of Trucks in Design Lane	95	-	-
Operational Speed	60	-	-
Traffic Growth Percent (Compound)	4	-	-
General Traffic Inputs			
Mean Wheel Location (in. from marking)	18	14	22
Traffic Wander (Sdev in.)	10	8	12
Design Lane Width (ft)	12	10	14
Tire Pressure Single (psi)	120	80	150
Tire Pressure Dual (psi)	120	80	150

2.1.4.3 Climate Variables, Table 2-43

The latitude and longitude were chosen to be between Houston and Beaumont. Two weather stations were chosen to represent this pavement. The minimum and maximum values for latitude and longitude were chosen to represent the maximum deviation that could be achieved while maintaining those same two stations. Larger variation would remove a station from the list of nearby stations. The elevations and depth to water table were selected as representative of the area.

Table 2-43. Climate Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Jointed Plain Concrete Pavements.

Environment/Climate	Wet-Warm		
	Mid	Min	Max
Latitude	29.4	28.3	30
Longitude	93.8	93	94.5
Elevation (ft)	20	2	50
Depth of Water Table (ft)	20	1	50

2.1.4.4 JPCP Design Feature Variables, Table 2-44

The shoulder type that was chosen is the best type available, and what is normally used in TxDOT. The default curl/warp temperature was used and the range was provided by TTI. The steel parameters and crack spacing were provided by TxDOT, while the default program values were used for the variables concerning the base.

Table 2-44. JPCP Design Feature Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Jointed Plain Concrete Pavements.

JPCP Design Features	Wet-Warm		
	Mid	Min	Max
Permanent Curl/Warp Temp Diff (°F)	-10	-6	-15
Joint Spacing (ft)	15	12.5	18
Joint Spacing Random	-	Y	-
Joint Sealant Type	Liquid	None	Silicone
Dowels	Y	N	-
Dowel Bar Diameter (in.)	1.25	1.00	1.50
Dowel Bar Spacing (in.)	12	10	14
Shoulder Type	Tied	AC	-
Long Term LTE (%)	70	50	90
Widened Slab (ft)	-	12	14
Widened and Tied	-	12@50%	14@90%
Base Erodibility Index (1-5)	3	4	1
PCC-Base Interface	Unbonded	Bonded	
Loss of Bond Age (Months)	60	24	96

2.1.4.5 Drainage and Surface Property Variables, Table 2-45

The program default value for the surface shortwave absorptivity was taken as the base value, while the variation was taken from a Purdue University lecture on meteorology: http://www.eas.purdue.edu/atms535/lecture4/lecture4.html

The other variables were program defaults and reasonable ranges.

Table 2-45. Drainage and Surface Property Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Jointed Plain Concrete Pavements.

Drainage and Surface Properties	Wet-Warm		
	Mid	Min	Max
Surface Shortwave Absorptivity	0.85	0.80	0.90
Infiltration	Mod	Ext	Min
Drainage Path Length (ft)	12	10	15
Pavement Cross Slope (%)	2	0	4

2.1.4.6 JPCP Mix Design Variables, Table 2-46

The cement content and w/c ratio were provided by TxDOT. Other values and ranges were program defaults and best estimates of TTI personnel.

Table 2-46. JPCP Mix Design Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Jointed Plain Concrete Pavements.

CRCP Mix Design	Wet-Warm		
	Mid	Min	Max
Cement Type	I	II	III
Cement Content (lb/yd^3)	517	470	564
Water/Cement Ratio	0.45	0.48	0.42
Aggregate Type	Lime	Chert/Grav	Basalt
PCC Zero-stress Temp (°F)	107	90	130
Reversible Shrinkage (% Ultimate)	50	25	75
Days to Develop 50% Ultimate Shrink	45	30	60
Curing Method	CC		Wet

2.1.4.7 JPCP Strength Variables, Table 2-47

The 28-day strengths were provided by TxDOT, while the strength data for other times were provided by TTI.

Table 2-47. JPCP Strength Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Jointed Plain Concrete Pavements.

JPCP Strength	Wet-Warm		
	Mid	Min	Max
Level 3, 28 day Mod of Rupture (psi)	620	580	670
Level 3, 28 day Compr. Strength (psi)	4000	3200	5000
Level 2, 7 day Compr. Strength (psi)	1500	1300	1800
Level 2, 14 day Compr. Strength (psi)	2000	1750	2500
Level 2, 28 day Compr. Strength (psi)	4000	3200	5000
Level 2, 90 day Compr. Strength (psi)	4500	3500	5500
20 Yr/28 day Compressive Strength	1.35	1.2	1.5
Level 1, 7 day E (ksi)	2000	1800	2300
Level 1, 14 day E (ksi)	2900	2600	3400
Level 1, 28 day E (ksi)	3500	3000	4000
Level 1, 90 day E (ksi)	4000	3500	4500
20 Yr/28 day E	1.35	1.2	1.5
Level 1, 7 day Mr (psi)	300	250	350
Level 1, 14 day Mr (psi)	500	450	550
Level 1, 28 day Mr (psi)	620	580	670
Level 1, 90 day Mr (psi)	650	600	750
20 Yr/28 day Mr	1.35	1.2	1.5

2.1.4.8 JPCP Thermal Variables, Table 2-48

The unit weight and Poisson's ratio were provided by TxDOT, the thermal contraction came from experts at TTI, while the thermal conductivity and heat capacity were taken from Johnston et al. 1981a and Johnston et al. 1981b.

Table 2-48. JPCP Thermal Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Jointed Plain Concrete Pavements.

JPCP Thermal Properties	Wet-Warm		
	Mid	Min	Max
Thickness (in.)	10	9	11
Unit Weight (pcf)	145	140	150
Poisson's Ratio	0.15	0.10	0.20
Coefficient of Thermal Contract (°F×10^{-6})	6	4	9
Ultimate Shrink at 40%RH (Microstrain)	643	500	800
Thermal Conductivity (BTU/hr-ft-°F)	1.5	1.4	1.7
Heat Capacity (BTU/lb-°F)	0.28	0.25	0.30

2.1.4.9 AC Layer Binder Property Variables, Table 2-49

Typical AC binder types were identified. While listed as a base value, the options provided by the program are for either PG or conventionally graded binders. Therefore, the conventional binders were compared to the base value for the Superpave binders. Only Level 3 data were entered for the HMAC layer.

Table 2-49. AC Layer Binder Property Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Jointed Plain Concrete Pavements.

AC Layer Binder Properties	Wet-Warm		
	Mid	Min	Max
Superpave Binder	70-22	64-16	76-28
Conventional Viscosity Grade	20	10	30

2.1.4.10 AC Layer General Property Variables, Table 2-50

Typical AC layer properties were entered, and the thermal conductivity and heat capacity were taken from Johnston et al. 1981a and Johnston et al. 1981b.

Table 2-50. AC Layer General Property Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Jointed Plain Concrete Pavements.

AC Layer General Properties	Wet-Warm		
	Mid	Min	Max
Reference Temperature (°F)	70	65	75
Effective Binder Content (% by Vol.)	11	8	14
Air Voids (%)	8.5	6.5	11
Total Unit Wt (pcf)	148	142	154
Poisson's Ratio	0.35	0.30	0.40
Thermal Conductivity (BTU/hr-ft-°F)	0.67	0.53	0.81
Heat Capacity (BTU/lb-°F)	0.23	0.30	0.40

2.1.4.11 AC Layer Mix Variables, Table 2-51

Typical AC layer gradations were entered.

Table 2-51. AC Layer Mix Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Jointed Plain Concrete Pavements.

AC Layer Mix	Wet-Warm		
	Mid	Min	Max
Thickness (in.)	1	0	-
Cum % Retained 3/4"	10	0	20
Cum % Retained 3/8"	20	10	30
Cum % Retained #4	30	20	40
% Pass #200	6	4	8

2.1.4.12 Lime Treated Strength Variables, Table 2-52

The version of the M-E Design Guide used in this part of the analysis (0.502) does not include a designation for lime treated soil. Therefore, best estimates for the base values and ranges were provided by TTI and TxDOT personnel.

Table 2-52. Lime Treated Strength Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Jointed Plain Concrete Pavements.

Lime Treated CH Soil Strength	Base	Min	Max
Thickness (in.)	6.0	4.0	8.0
Level 3 - Poisson's Ratio	0.30	0.15	0.40
Level 3 - Coefficient of Lateral Pressure K_o	0.50	0.40	0.60
Level 3 - Modulus (ksi)	35	25	45

2.1.4.13 Lime Treated ICM Variables, Table 2-53

The version of the M-E Design Guide used in this part of the analysis (0.088) does not include a designation for lime treated soil. Therefore, best estimates for the base values and ranges were provided by TTI and TxDOT personnel. The saturated hydraulic conductivity was estimated from Freeze and Cherry (1979), and the soil water characteristic curve was taken from Fredlund and Xing (1994).

Table 2-53. Lime Treated ICM Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Jointed Plain Concrete Pavements.

Lime Treated CH Soil ICM	Wet-Warm		
	Base	Min	Max
Level 3 - ICM Inputs or Representative Value	I	-	R
Level 3 - Plasticity Index	2	0	6
Level 3 - Passing #200 (%)	10	0	20, 80
Level 3 - Passing #4 (%)	95	85	100
Level 3 - D60 (mm)	2.0	0.5	4.0
Level 3 - Maximum Dry Unit Wt (pcf)	122	110	130
Level 3 - Specific Gravity of Solids	2.68	2.62	2.74
Level 3 - Saturated Hydraulic Conductivity (ft/hr)	37	10	55
Level 3 - Optimum Gravimetric Water Content (%)	11.2	8.0	14.0
Level 3 - Soil Water Characteristic Curve			
af	19	1.95	15150
bf	4.1	2.7	1.1
cf	1.2	1.08	0.865
Hr	3000	3000	5000
Level 3 - Compacted or Uncompacted	C	U	-
Level 2 - Seasonal Values (Vary up and down by 2k)	Y	-	-

2.1.4.14 Wet-Warm Subgrade (CH) Strength Variables, Table 2-54

The thickness and modulus of the subgrade were estimated values from TxDOT and TTI personnel. Program default values were used for the other base values.

Table 2-54. Wet-Warm Subgrade (CH) Strength Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Jointed Plain Concrete Pavements.

Subgrade (CH) ICM	Wet-Warm		
	Mid	Min	Max
Thickness (in.)	75	50	100
Level 3 - Poisson's Ratio	0.35	0.30	0.40
Level 3 - Coefficient of Lateral Pressure Ko	0.50	0.40	0.60
Level 3 - Modulus (ksi)	8	5	11
Level 3 - ICM Inputs or Representative Value	I	I	R
Level 2 - Seasonal Values (Vary up and down by 2k)	Y	Y	Y

2.1.4.15 Wet-Warm Subgrade (CH) ICM Variables, Table 2-55

The best estimates for the base values and ranges were provided by TTI and TxDOT personnel. Program default values were used for the other base values. The saturated hydraulic conductivity was estimated from Freeze and Cherry (1979), and the soil water characteristic curve was taken from Fredlund and Xing (1994).

Table 2-55. Wet-Warm Subgrade (CH) ICM Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Jointed Plain Concrete Pavements.

Subgrade (CH) Strength	Wet-Warm		
	Mid	Min	Max
Level 3 - Plasticity Index	35	25	45
Level 3 - Passing #200 (%)	75	65	85
Level 3 - Passing #4 (%)	95	-	-
Level 3 - D60 (mm)	0.01	0.003	0.02
Level 3 - Maximum Dry Unit Wt (pcf)	96.7	80	120
Level 3 - Specific Gravity of Solids	2.76	2.66	2.86
Level 3 - Saturated Hydraulic Conductivity (ft/hr)	2.2×10^{-7}	1×10^{-8}	1×10^{-6}
Level 3 - Optimum Gravimetric Water Content (%)	25.1	15	35
Level 3 - Soil Water Characteristic Curve			
af	323	200	450
bf	0.989	0.8	1.1
cf	0.735	0.60	0.85
Hr	1.7×10^{-4}	1×10^{-3}	1×10^{-5}
Level 3 - Compacted or Uncompacted	C	U	-

2.1.4.16 Bedrock Variables, Table 2-56

The best estimates for the base values and ranges were provided by TTI and TxDOT personnel.

Table 2-56. Bedrock Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Jointed Plain Concrete Pavements.

Bedrock	Wet-Warm		
	Mid	Min	Max
Massive and Continuous or Fractured	M	F	
Unit Weight (pcf)	120	100	140
Poisson's Ratio	0.35	0.30	0.40
Resilient Modulus (ksi)	1000	800	1200

Appendix K contains the results of the sensitivity analysis for the Wet-Warm, JPCP runs.

2.1.5 Asphalt Concrete Overlay of Asphalt Concrete Pavements (AC/AC)

Asphalt overlays of asphalt pavements are used throughout Texas on low, medium, and high volume routes. The M-E Design Guide input requires the types and thicknesses of each layer. Since the analysis has to be conducted on specific thicknesses of HMAC, a typical overlay thickness was used. The underlying pavement was the same as used for the Dry-Cold analysis. Most of the parameters used in that analysis were also used for this case. The pavement layers in Table 2-57 were used to evaluate the M-E Design Guide for asphalt overlays of asphalt pavements.

Table 2-57. Layer Types and Thicknesses Used in M-E Pavement Design Guide Sensitivity Analysis of Asphalt Concrete Overlays of Asphalt Concrete Pavements.

Layers	AC/AC
Overlay	4.0" HMAC
Surface	8.5" HMAC
Granular Base	6.0" Crushed Stone
*Treated Layer	6.0" Lime Treated
Subgrade	75.0" ML
Bedrock	-

* - The version of the M-E Design Guide used in this part of the analysis (0.502) does not include a specific designation for lime treated soil. Equivalent variables were entered.

With the above layer types and thicknesses, an input file was created for each situation. The tables below list the data for each case. If no value is given for the minimum (Min) or maximum (Max), the variable was not changed. Sometimes this was done because the variable would have no impact (traffic direction) or because changing that variable would have an unnecessary impact (design life). When the value of the variable depends upon whether the pavement was thin, intermediate, or thick (as in the AADTT), values are listed in that order, separated by a "/."

2.1.5.1 General Variables, Table 2-58

The design life, construction dates, length of time between operations, and initial IRI are all based on typical values for asphalt concrete pavements. The functional class was varied from primary arterial (PA) to minor arterial (MA) to local road (LR), to ensure a range of values. The highest value (PA) was used as the default because it was expected that the M-E Design Guide would most likely be used on the highest volume routes.

Table 2-58. General Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Asphalt Concrete Overlays of Asphalt Concrete Pavements.

General Information	AC/AC		
	Base	Min	Max
Design Life (years)	8	-	-
Existing Pavement Construction Month	September 1991	July	November
Overlay Construction Month	June 2003	August	January
Traffic Open Month	+2 Months	+1 Month	+ 6 Months
Functional Class	PA	MA	LR
Traffic Direction	E	-	-

2.1.5.2 Traffic Variables, Table 2-59

For the traffic variables, the average annual daily truck traffic was based on the values used in the previous analysis.

While not normally an input that a pavement designer would consider, the lane width, wander, wheel location, and tire pressures were included in the experiment design to illustrate the impacts of these variables.

2.1.5.3 Climate Variables, Table 2-60

The climatic variables were the same as chosen for the previous analysis.

2.1.5.4 Thermal Cracking Variables, Table 2-61

The thermal variables were the same as chosen for the previous analysis.

Table 2-59. Traffic Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Asphalt Concrete Overlays of Asphalt Concrete Pavements.

Traffic	AC/AC		
	Base	Min	Max
Two-Way AADTT (9200 AADT, 12.6% Trucks)	1159	966	1391
Number of Lanes	2	-	-
Percent of Trucks in Design Direction	100	-	-
Percent of Trucks in Design Lane	95	-	-
Operational Speed	60	-	-
Traffic Growth Percent (Compound)	1.67	-	-
General Traffic Inputs			
Mean Wheel Location (in. from marking)	18	14	22
Traffic Wander (SDev in.)	10	8	12
Design Lane Width (ft)	12	10	14
Tire Pressure Single (psi)	120	80	150
Tire Pressure Dual (psi)	120	80	150

Table 2-60. Climate Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Asphalt Concrete Overlays of Asphalt Concrete Pavements.

Environment/Climate	AC/AC		
	Base	Min	Max
Latitude	34	33.2	35
Longitude	101.5	100.5	102.5
Elevation (ft)	3500	2000	5000
Depth of Water Table (ft)	50	1	100
Surface Shortwave Absorptivity	0.85	0.80	0.90

Table 2-61. Thermal Cracking Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Asphalt Concrete Overlays of Asphalt Concrete Pavements.

Thermal Cracking	All Designs		
	Base	Min	Max
Average Tensile Strength at 14 °F (psi)	421	350	500
Creep Test Duration (sec)	100	-	-
Creep Compliance (1/psi) (Levels 1 and 2)			
Level 2, Creep Compl - All Times and Temperatures	Default	/2	×5
Level 1, Creep Compl - All Times and Temperatures	Default	/2	×5
Compute Mix Coefficient of Contraction	1.30×10^{-5}	1.30×10^{-6}	1.30×10^{-4}
Mixture VMA	15.7	14	17.4
Aggregate Coefficient of Contraction	5.0×10^{-6}	3.0×10^{-6}	7.0×10^{-6}

2.1.5.5 Flexible Rehabilitation Variables, Table 2-63

This portion of the Guide was not well documented at the time of this analysis, so best guesses of the required data and reasonable ranges were used. Any entries for Level 1 rehabilitation caused the program to shut down, so this variable was not evaluated.

Table 2-63. Flexible Rehabilitation Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Asphalt Concrete Overlays of Asphalt Concrete Pavements.

Flexible Rehabilitation	AC/AC		
	Base	Min	Max
Overlay Interface Factor	1.0	0.3	0.8
Original Surface Interface Factor	1.0	0.3	0.8
Granular Base Layer Interface Factor	1.0	0.3	0.8
Stabilized Subgrade Interface Factor	1.0	0.3	0.8
All Layers Interface Factor	1.0	0.3	0.8
Rehabilitation Level 1	Failed		
Pavement Rating	Fair	Poor	Good
Total Rutting	0.60	0.70	0.50

2.1.5.6 Asphalt Concrete Overlay Mix Variables, Table 2-64

The mix variables were the same as chosen for the previous analysis.

Table 2-64. Asphalt Concrete Overlay Mix Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Asphalt Concrete Overlays of Asphalt Concrete Pavements.

Asphalt Concrete Overlay Mix	Mid	Min	Max
Overlay Thickness (in.)	4.0	3.0	5.0
Level 3,2, Cum % Retained 3/4"	10	0	20
Level 3,2, Cum % Retained 3/8"	20	10	30
Level 3,2, Cum % Retained #4	30	20	40
Level 3,2, % Pass #200	6	4	8
Level 3,2, All Gradations	-	Low	High
Level 1, Dynamic Modulus (based on grade of asphalt)	Mid	Base/1.5	Base×1.5

No other variables were run due to time constraints. Appendix L contains the results of the sensitivity analysis for the asphalt concrete overlays of asphalt concrete pavements.

2.1.6 Bonded Concrete Overlay of Continuously Reinforced Concrete Pavements

The rehabilitation of CRC pavement included the option to evaluate bonded concrete overlays. While this is used in Texas, it is not widely used. The values from the previous analysis were used, along with the new entries required by the M-E Pavement Design Guide. Table 2-65 lists the material types and thickness used in the evaluation of the M-E Design Guide.

The layer types and thicknesses from Table 2-65 were used to create an input file for each situation. The tables below list the data for each case. If no value is given for the minimum (Min) or maximum (Max), the variable was not changed. Sometimes this was done because the variable would have no impact (traffic direction) or because changing that variable would have an unnecessary impact (design life).

2.1.6.1 General Variables, Table 2-66

The variables were the same as chosen for the previous analysis.

Table 2-65. Layer Types and Thicknesses Used in M-E Pavement Design Guide Sensitivity Analysis of Bonded Concrete Overlay on Continuously Reinforced Concrete Pavements.

Layers	Dry-Cold	Wet-Warm
Bonded Concrete Overlay	2.0"	2.0"
Existing CRCP Surface	13.0"	13.0"
AC Layer	4.0" HMAC	1.0" HMAC
Cement Stabilized Base		6.0" Cement Stabilized
*Treated Layer	8.0" Lime Treated	8.0" Lime Treated
Subgrade	100" Silt (ML)	100" Clay (CH)
Bedrock	-	-

* - The version of the M-E Design Guide used in this part of the analysis (0.502) does not include a specific designation for lime treated soil. Equivalent variables were entered.

Table 2-66. General Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Bonded Concrete Overlay on Continuously Reinforced Concrete Pavements.

General Information	Dry-Cold			Wet-Warm		
	Mid	Min	Max	Mid	Min	Max
Design Life (years)	20	-	-	20	-	-
Overlay Construction Month	June	Jan-Oct	Aug	June	Jan-Oct	Aug
Existing Construction Month	June	-	-	June	-	-
Traffic Open Month	+2 Months	+1 Month	+ 6 Month	+ 2 Month	+1 Month	+ 6 Month
Functional Class	PA	MA	LR	PA	MA	LR
Traffic Direction	E			E		

2.1.6.2 Traffic Variables, Table 2-67

The variables were the same as chosen for the previous analysis.

2.1.6.3 Climate Variables, Table 2-68

The variables were the same as chosen for the previous analysis.

Table 2-67. Traffic Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Bonded Concrete Overlay on Continuously Reinforced Concrete Pavements.

Traffic	Dry-Cold			Wet-Warm		
	Mid	Min	Max	Mid	Min	Max
Two-Way AADTT (40000 AADT, 20% Trucks)	8000	6400	9600	8000	6400	9600
Number of Lanes	2	-	-	2	-	-
Percent of Trucks in Design Direction	50	-	-	50	-	-
Percent of Trucks in Design Lane	95	-	-	95	-	-
Operational Speed	60	-	-	60	-	-
Traffic Growth Percent (Compound)	4	-	-	4	-	-
General Traffic Inputs						
Mean Wheel Location (in. from marking)	18	14	22	18	14	22
Traffic Wander (Sdev in.)	10	8	12	10	8	12
Design Lane Width (ft)	12	10	14	12	10	14
Tire Pressure Single (psi)	120	80	150	120	80	150
Tire Pressure Dual (psi)	120	80	150	120	80	150

Table 2-68. Climate Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Bonded Concrete Overlay on Continuously Reinforced Concrete Pavements.

Environment/Climate	Dry-Cold CRC/4"AC			Wet-Warm CRC/1"AC/CTB		
	Mid	Min	Max	Mid	Min	Max
Latitude	34	33.2	35	29.4	28.3	30
Longitude	101.5	100.5	102.5	93.8	93	94.5
Elevation (ft)	3500	2000	5000	20	2	50
Depth of Water Table (ft)	50	1	100	20	1	50

2.1.6.4 CRCP Design Feature Variables, Table 2-69

The variables were the same as chosen for the previous analysis. In some cases, the variables apply to all concrete layers. For example, there is only one entry location for steel reinforcement and it can not be varied by layer.

Table 2-69. CRCP Design Feature Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Bonded Concrete Overlay on Continuously Reinforced Concrete Pavements.

CRCP Design Features	Dry-Cold CRC/4"AC			Wet-Warm CRC/1"AC/CTB		
	Mid	Min	Max	Mid	Min	Max
Shoulder Type	Tied	AC	-	Tied	AC	-
Permanent Curl/Warp Temp Diff (°F)	-10	-6	-15	-10	-6	-15
Steel Reinforcement (%)	0.6	0.4	0.8	0.6	0.4	0.8
Bar Diameter (in.)	0.625	0.500	0.750	0.625	0.500	0.750
Steel Depth (in.)	½ T	¼ T		½ T	¼ T	
Base Erodibility Index (1-5)	3	4	1	3	4	1
Base/Slab Friction Coefficient	7.1	3.7	10	7.1	3.7	10
Generate Crack Spacing Using Model	Y	-	-	Y	-	-
Enter Mean Crack Spacing (in.)	48	30	72	48	30	72

2.1.6.5 Drainage and Surface Property Variables, Table 2-70

The variables were the same as chosen for the previous analysis.

Table 2-70. Drainage and Surface Property Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Bonded Concrete Overlay on Continuously Reinforced Concrete Pavements.

Drainage and Surface Properties	Dry-Cold CRC/4"AC			Wet-Warm CRC/1"AC/CTB		
	Mid	Min	Max	Mid	Min	Max
Surface Shortwave Absorptivity	0.85	0.80	0.90	0.85	0.80	0.90
Infiltration	Min	Mod	Neg	Mod	Ext	Min
Drainage Path Length (ft)	12	10	15	12	10	15
Pavement Cross Slope (%)	2	0	4	2	0	4

2.1.6.6 CRCP Mix Design Variables, Table 2-71

The variables were the same as chosen for the previous analysis.

Table 2-71. CRCP Mix Design Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Bonded Concrete Overlay on Continuously Reinforced Concrete Pavements.

CRCP Mix Design	Dry-Cold CRC/4"AC			Wet-Warm CRC/1"AC/CTB		
	Mid	Min	Max	Mid	Min	Max
Overlay Cement Type	I	-	-	I	-	-
Existing Cement Type	I	-	-	I	-	-
Overlay Cement Content (lb/yd^3)	517	470	564	517	470	564
Existing Cement Content (lb/yd^3)	517	470	564	517	470	564
Overlay Water/Cement Ratio	0.45	0.48	0.42	0.45	0.48	0.42
Existing Water/Cement Ratio	0.45	0.48	0.42	0.45	0.48	0.42
Overlay Aggregate Type	Lime	Chert/Grav	Granit	Lime	Chert/Grav	Basalt
Existing Aggregate Type	Lime	Chert/Grav	Basalt	Lime	Chert/Grav	Basalt
Overlay PCC Zero-stress Temp (°F)	107	90	130	107	90	130
Existing PCC Zero-stress Temp (°F)	107	90	130	107	90	130
Reversible Shrinkage (% Ultimate)	50	25	75	50	25	75
Overlay Days to 50% Ultimate Shrink	45	30	60	45	30	60
Overlay Curing Method	CC		Wet	CC		Wet

2.1.6.7 CRCP Strength Variables, Table 2-72

The variables were the same as chosen for the previous analysis. Table 2-72 has the values for the bonded concrete overlay layer, and Table 2-73 has the values for the existing layer.

Table 2-72. CRCP Overlay Strength Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Bonded Concrete Overlay over Continuously Reinforced Concrete Pavements.

CRCP Strength	Dry-Cold CRC/4"AC			Wet-Warm CRC/1"AC/CTB		
	Mid	Min	Max	Mid	Min	Max
Level 3, 28 day Mod of Rupture (psi)	620	580	670	620	580	670
Level 3, 28 day Compr. Strength (psi)	4000	3200	5000	4000	3200	5000
Level 2, 7 day Compr. Strength (psi)	1500	1300	1800	1500	1300	1800
Level 2, 14 day Compr. Strength (psi)	2000	1750	2500	2000	1750	2500
Level 2, 28 day Compr. Strength (psi)	4000	3200	5000	4000	3200	5000
Level 2, 90 day Compr. Strength (psi)	4500	3500	5500	4500	3500	5500
20 Yr/28 day Compressive Strength	1.35	1.2	1.5	1.35	1.2	1.5
Level 1, 7 day Compr. Strength (psi)	1500	1300	1800	1500	1300	1800
Level 1, 14 day Compr. Strength (psi)	2000	1750	2500	2000	1750	2500
Level 1, 28 day Compr. Strength (psi)	4000	3200	5000	4000	3200	5000
Level 1, 90 day Compr. Strength (psi)	4500	3500	5500	4500	3500	5500
20 Yr/28 day Compressive Strength	1.35	1.2	1.5	1.35	1.2	1.5
Level 1, 7 day E (ksi)	2000	1300	2300	2000	1800	2300
Level 1, 14 day E (ksi)	2900	1750	3400	2900	2600	3400
Level 1, 28 day E (ksi)	3500	3200	4000	3500	3000	4000
Level 1, 90 day E (ksi)	4000	3500	4500	4000	3500	4500
20 Yr/28 day E	1.35	1.2	1.5	1.35	1.2	1.5
Level 1, 7 day Mr (psi)	300	250	350	300	250	350
Level 1, 14 day Mr (psi)	500	450	550	500	450	550
Level 1, 28 day Mr (psi)	620	580	670	620	580	670
Level 1, 90 day Mr (psi)	650	600	750	650	600	750
20 Yr/28 day Mr	1.35	1.2	1.5	1.35	1.2	1.5

Table 2-73. CRCP Existing Strength Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Bonded Concrete Overlay on Continuously Reinforced Concrete Pavements.

CRCP Strength	Dry-Cold CRC/4"AC			Wet-Warm CRC/1"AC/CTB		
	Mid	Min	Max	Mid	Min	Max
Level 3, 28 day Mod of Rupture (psi)	620	580	670	620	580	670
Level 3, 28 day Compr. Strength (psi)	4000	3200	5000	4000	3200	5000
Level 2, 7 day Compr. Strength (psi)	1500	1300	1800	1500	1300	1800
Level 2, 14 day Compr. Strength (psi)	2000	1750	2500	2000	1750	2500
Level 2, 28 day Compr. Strength (psi)	4000	3200	5000	4000	3200	5000
Level 2, 90 day Compr. Strength (psi)	4500	3500	5500	4500	3500	5500
20 Yr/28 day Compressive Strength	1.35	1.2	1.5	1.35	1.2	1.5
Level 1, 7 day Compr. Strength (psi)	1500	1300	1800	1500	1300	1800
Level 1, 14 day Compr. Strength (psi)	2000	1750	2500	2000	1750	2500
Level 1, 28 day Compr. Strength (psi)	4000	3200	5000	4000	3200	5000
Level 1, 90 day Compr. Strength (psi)	4500	3500	5500	4500	3500	5500
20 Yr/28 day Compressive Strength	1.35	1.2	1.5	1.35	1.2	1.5
Level 1, 7 day E (ksi)	2000	1300	2300	2000	1800	2300
Level 1, 14 day E (ksi)	2900	1750	3400	2900	2600	3400
Level 1, 28 day E (ksi)	3500	3200	4000	3500	3000	4000
Level 1, 90 day E (ksi)	4000	3500	4500	4000	3500	4500
20 Yr/28 day E	1.35	1.2	1.5	1.35	1.2	1.5
Level 1, 7 day Mr (psi)	300	250	350	300	250	350
Level 1, 14 day Mr (psi)	500	450	550	500	450	550
Level 1, 28 day Mr (psi)	620	580	670	620	580	670
Level 1, 90 day Mr (psi)	650	600	750	650	600	750
20 Yr/28 day Mr	1.35	1.2	1.5	1.35	1.2	1.5

2.1.6.8 CRCP Thermal Variables, Table 2-74

The variables were the same as chosen for the previous analysis.

Table 2-74. CRCP Thermal Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Bonded Concrete Overlay on Continuously Reinforced Concrete Pavements.

CRCP Thermal Properties	Dry-Cold			Wet-Warm		
	Mid	Min	Max	Mid	Min	Max
Overlay Thickness (in.)	2.0	1.5	3.0	2.0	1.5	3.0
Exist Thickness (in.)	13.0	11.0	15.0	13.0	11.0	15.0
Overlay Unit Weight (pcf)	145	140	150	145	140	150
Exist Unit Weight (pcf)	145	140	150	145	140	150
Overlay Poisson's Ratio	0.15	0.10	0.20	0.15	0.10	0.20
Exist Poisson's Ratio	0.15	0.10	0.20	0.15	0.10	0.20
Overlay Coeff. of Thermal Contract (°F×10^{-6})	6	4	9	6	4	9
Exist Coeff. of Thermal Contract (°F×10^{-6})	6	4	9	6	4	9
Overlay Ultimate Shrink @40%RH (Microstrain)	643	500	800	643	500	800
Exist Ultimate Shrink at 40%RH (Microstrain)	643	500	800	643	500	800
Overlay Thermal Conductivity (BTU/hr-ft-°F)	1.5	1.4	1.7	1.5	1.4	1.7
Exist Thermal Conductivity (BTU/hr-ft-°F)	1.5	1.4	1.7	1.5	1.4	1.7
Overlay Heat Capacity (BTU/lb-°F)	0.28	0.25	0.30	0.28	0.25	0.30
Exist Heat Capacity (BTU/lb-°F)	0.28	0.25	0.30	0.28	0.25	0.30

2.1.6.9 AC Layer Binder Property Variables, Table 2-75

The variables were the same as chosen for the previous analysis.

Table 2-75. AC Layer Binder Property Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Bonded Concrete Overlay on Continuously Reinforced Concrete Pavements.

AC Layer Binder Properties	Dry-Cold			Wet-Warm		
	Mid	Min	Max	Mid	Min	Max
Superpave Binder	64-28	58-22	70-34	70-22	64-16	76-28
Conventional Viscosity Grade	10	5	20	20	10	30

2.1.6.10 AC Layer General Property Variables, Table 2-76

The variables were the same as chosen for the previous analysis.

Table 2-76. AC Layer General Property Variables and Ranges for M-E Pavement Design Guide Sensitivity of Analysis Bonded Concrete Overlay on Continuously Reinforced Concrete Pavements.

AC Layer General Properties	Dry-Cold			Wet-Warm		
	Mid	Min	Max	Mid	Min	Max
Reference Temperature (°F)	70	65	75	70	65	75
Effective Binder Content (% by Vol.)	11	8	14	11	8	14
Air Voids (%)	8.5	6.5	11	8.5	6.5	11
Total Unit Wt (pcf)	148	142	154	148	142	154
Poisson's Ratio	0.35	0.30	0.40	0.35	0.30	0.40
Thermal Conductivity (BTU/hr-ft-°F)	0.67	0.53	0.81	0.67	0.53	0.81
Heat Capacity (BTU/lb-°F)	0.23	0.30	0.40	0.23	0.30	0.40

2.1.6.11 AC Layer Mix Variables, Table 2-77

The variables were the same as chosen for the previous analysis.

Table 2-77. AC Layer Mix Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Bonded Concrete Overlay on Continuously Reinforced Concrete Pavements.

AC Layer Mix	Dry-Cold			Wet-Warm		
	Mid	Min	Max	Mid	Min	Max
Thickness (in.)	4	3	5	1	1	2
Cum % Retained 3/4"	10	0	20	10	0	20
Cum % Retained 3/8"	20	10	30	20	10	30
Cum % Retained #4	30	20	40	30	20	40
% Pass #200	6	4	8	6	4	8

2.1.6.12 Lime Treated Strength Variables, Table 2-78

The variables were the same as chosen for the previous analysis.

2.1.6.13 Lime Treated ICM Variables, Table 2-79

The variables were the same as chosen for the previous analysis.

Table 2-78. Lime Treated Strength Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Bonded Concrete Overlay on Continuously Reinforced Concrete Pavements.

Lime Treated Strength	Dry-Cold			Wet-Warm		
	Mid	Min	Max	Mid	Min	Max
Thickness (in.)	8	6	10	8	6	10
Poisson’s Ratio	0.2	0.15	0.3	0.2	0.15	0.3
Resilient Modulus (ksi)	150	50	300	150	50	300

Table 2-79. Lime Treated ICM Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Bonded Concrete Overlay on Continuously Reinforced Concrete Pavements.

Lime Treated CH Soil ICM	Base	Min	Max
Level 3 - ICM Inputs or Representative Value	I	-	R
Level 3 - Plasticity Index	2	0	6
Level 3 - Passing #200 (%)	10	0	20, 80
Level 3 - Passing #4 (%)	95	85	100
Level 3 - D60 (mm)	2.0	0.5	4.0
Level 3 - Maximum Dry Unit Wt (pcf)	122	110	130
Level 3 - Specific Gravity of Solids	2.68	2.62	2.74
Level 3 - Saturated Hydraulic Conductivity (ft/hr)	37	10	55
Level 3 - Optimum Gravimetric Water Content (%)	11.2	8.0	14.0
Level 3 - Soil Water Characteristic Curve			
af	19	1.95	15150
bf	4.1	2.7	1.1
cf	1.2	1.08	0.865
Hr	3000	3000	5000
Level 3 - Compacted or Uncompacted	C	U	-
Level 2 - Seasonal Values (Vary up and down by 2k)	Y	-	-

2.1.6.14 Dry-Cold Subgrade (ML) Strength Variables, Table 2-80

The variables were the same as chosen for the previous analysis.

Table 2-80. Dry-Cold Subgrade (ML) Strength Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Bonded Concrete Overlay on Continuously Reinforced Concrete Pavements..

Subgrade (ML) Strength	Dry-Cold		
	Mid	Min	Max
Thickness (in.)	100	50	150
Level 3 - Poisson's Ratio	0.35	0.30	0.40
Level 3 - Coefficient of Lateral Pressure K_o	0.50	0.40	0.60
Level 3 - Modulus (ksi)	20	10	30
Level 3 - ICM Inputs or Representative Value	I	-	R
Level 3 - Compacted or Uncompacted	C	U	-
Level 2 - Seasonal Values (Vary up and down by 2k)	Y	Y	Y

2.1.6.15 Dry-Cold Subgrade (ML) ICM Variables, Table 2-81

The variables were the same as chosen for the previous analysis.

Table 2-81. Dry-Cold Subgrade (ML) ICM Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Bonded Concrete Overlay on Continuously Reinforced Concrete Pavements.

Subgrade (ML) ICM	Dry-Cold		
	Mid	Min	Max
Level 3 - Plasticity Index	10	5	15
Level 3 - Passing #200 (%)	80	70	90
Level 3 - Passing #4 (%)	95	-	-
Level 3 - D60 (mm)	0.05	0.02	0.08
Level 3 - Maximum Dry Unit Wt (pcf)	111.2	90	130
Level 3 - Specific Gravity of Solids	2.72	2.67	2.78
Level 3 - Saturated Hydraulic Conductivity (ft/hr)	6.23×10^{-6}	1×10^{-7}	4×10^{-4}
Level 3 - Optimum Gravimetric Water Content (%)	16.9	15	19
Level 3 - Soil Water Characteristic Curve			
af	46.9	30	60
bf	1.21	1.00	1.50
cf	0.635	0.50	1.00
Hr	1.76×10^{-3}	1×10^{-2}	1×10^{-4}
Level 3 - Compacted or Uncompacted	C	U	-

2.1.6.16 Wet-Warm Subgrade (CH) Strength Variables, Table 2-82

The variables were the same as chosen for the previous analysis.

Table 2-82. Wet-Warm Subgrade (CH) Strength Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Bonded Concrete Overlay on Continuously Reinforced Concrete Pavements.

Subgrade (CH) ICM	Wet-Warm		
	Mid	Min	Max
Thickness (in.)	100	50	150
Level 3 - Poisson's Ratio	0.35	0.30	0.40
Level 3 - Coefficient of Lateral Pressure K_o	0.50	0.40	0.60
Level 3 - Modulus (ksi)	8	5	11
Level 3 - ICM Inputs or Representative Value	I	I	R
Level 2 - Seasonal Values (Vary up and down by 2k)	Y	Y	Y

2.1.6.17 Wet-Warm Subgrade (CH) ICM Variables, Table 2-83

The variables were the same as chosen for the previous analysis.

Table 2-83. Wet-Warm Subgrade (CH) ICM Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Bonded Concrete Overlay on Continuously Reinforced Concrete Pavements.

Subgrade (CH) Strength	Wet-Warm		
	Mid	Min	Max
Level 3 - Plasticity Index	35	25	45
Level 3 - Passing #200 (%)	75	65	85
Level 3 - Passing #4 (%)	95	-	-
Level 3 - D60 (mm)	0.01	0.003	0.02
Level 3 - Maximum Dry Unit Wt (pcf)	96.7	80	120
Level 3 - Specific Gravity of Solids	2.76	2.66	2.86
Level 3 - Saturated Hydraulic Conductivity (ft/hr)	2.2×10^{-7}	1×10^{-8}	1×10^{-6}
Level 3 - Optimum Gravimetric Water Content (%)	25.1	15	35
Level 3 - Soil Water Characteristic Curve			
af	323	200	450
bf	0.989	0.8	1.1
cf	0.735	0.60	0.85
Hr	1.7×10^{-4}	1×10^{-3}	1×10^{-5}
Level 3 - Compacted or Uncompacted	C	U	-

2.1.6.18 Bedrock Variables, Table 2-84

The variables were the same as chosen for the previous analysis.

Table 2-84. Bedrock Variables and Ranges for M-E Pavement Design Guide Sensitivity Analysis of Bonded Concrete Overlay on Continuously Reinforced Concrete Pavements.

Bedrock	Dry-Cold			Wet-Warm		
	Mid	Min	Max	Mid	Min	Max
Massive and Continuous or Fractured	M	F		M	F	
Unit Weight (pcf)	120	100	140	120	100	140
Poisson's Ratio	0.35	0.30	0.40	0.35	0.30	0.40
Resilient Modulus (ksi)	1000	800	1200	1000	800	1200

Appendices M and N contain the results of the sensitivity analysis for the Dry-Cold and Wet-Warm, bonded concrete overlays on CRCP.

2.2 PRELIMINARY CALIBRATION

Once the base set of inputs was determined, the program was run with the national calibration values and the results recorded. In some cases, there was very little predicted distress. A very low quantity of distress made comparisons of the impact of the variables difficult to identify. When the quantity of longitudinal cracking is 10 ft per mile, an increase to 12 ft per mile is either a significant increase of 20 percent or an insignificant increase of 2 ft per mile. In addition, after 20 years of heavy traffic, more distress than this should have been expected. To counteract this problem, a preliminary set of regional calibration factors was developed that ensured a reasonable amount of distress. The following tables provide the development of the calibration factors with the intermediate values so that if future calibration is necessary, the impacts of the calibration constants are known.

The program should be calibrated with high quality data from Texas. However, the distress identification methodology (SHRP 1993) for the Strategic Highway Research Program (SHRP), which was used to calibrate the program, is considerably different from the typical TxDOT condition survey (TxDOT 2002). The SHRP definitions should be used in the calibration effort.

2.2.1 Preliminary Asphalt Concrete Pavement Calibration

The asphalt concrete pavement calibration constants Bf1, Bf2, and Bf3 modify the fatigue (alligator) cracking and C4 and C1 modify the top-down (longitudinal) cracking. As shown in Tables 2-85 to 2-90, there is considerable interaction between these variables.

An IRI value of 75 is a ride score of about 4.3, 100 is 3.8, 150 is 3.0, and 200 is 2.3.

Table 2-85. Calibration Constants for Dry-Cold, AC-Thin.

Dry-Cold, AC-Thin										
Long	Allig	Trans	AC Rut	Total Rut	IRI	Bf1	Bf2	Bf3	C4	C1
10.1	2E-04	0	0.067	0.393	114.2	1.0	1.00	1	1000	2.8
26.9	0.007	0	0.067	0.393	114.5	0.2	1.00	1	1000	2.8
40.9	0.033	0	0.067	0.393	114.9	0.1	1.00	1	1000	2.8
10600	100.0	0	0.067	0.393	1.57×10^{12}	0.2	0.20	1	1000	2.8
7670	100.0	0	0.067	0.393	15814.8	0.2	0.70	1	1000	2.8
1340	99.0	0	0.067	0.393	290.3	0.5	0.80	1	1000	2.8
458	24.6	0	0.067	0.393	129.1	1.0	0.85	1	1500	2.8
1530	24.6	0	0.067	0.393	129.1	1.0	0.85	1	5000	2.8
3070	84.0	0	0.067	0.393	163.8	0.3	0.85	1	5000	2.8
1580	31.1	0	0.067	0.393	131.3	0.3	0.88	1	5000	2.8
1300	31.1	0	0.067	0.393	131.3	0.3	0.88	1	5000	3.0
2060	16.7	0	0.067	0.393	126.2	0.3	0.89	1	5000	2.3
3400	31.1	0	0.067	0.393	131.3	0.3	0.88	1	5000	2.0
3050	23.1	0	0.067	0.393	128.5	0.3	0.885	1	5000	2.0

Table 2-86. Calibration Constants for Dry-Cold, AC-Intermediate.

Dry-Cold, AC-Intermediate										
Long	Allig	Trans	AC Rut	Total Rut	IRI	Bf1	Bf2	Bf3	C4	C1
1870	0.6	0	0.369	0.615	114	1	1.00	1	1000	2.8
33600	12.9	0	0.369	0.615	118	1	0.92	1	5000	2.8
9690	71.4	0	0.369	0.615	171	1	0.85	1	1000	2.8
7900	24.9	0	0.369	0.615	123	1	0.90	1	1000	2.8
8390	33.1	0	0.369	0.615	127	1	0.89	1	1000	2.8
3670	18.1	0	0.369	0.615	120	1	0.91	1	500	2.8
2370	24.9	0	0.369	0.615	123	1	0.90	1	300	2.8
3160	24.9	0	0.369	0.615	123	1	0.90	1	400	2.8

Table 2-87. Calibration Constants for Dry-Cold, AC-Thick.

Dry-Cold, AC-Thick										
Long	Allig	Trans	AC Rut	Total Rut	IRI	Bf1	Bf2	Bf3	C4	C1
508	4.57	0	0.47	0.684	120.6	1	1.00	1	1000	1
4880	11.1	0	0.47	0.684	122.6	1	0.95	1	3000	1
5980	26.4	0	0.47	0.684	128.2	1	0.92	1	2000	1
2990	26.4	0	0.47	0.684	128.2	1	0.92	1	1000	1

Table 2-88. Calibration Constants for Wet-Warm, AC-Thin.

Wet-Warm, AC-Thin										
Long	Allig	Trans	AC Rut	Total Rut	IRI	Bf1	Bf2	Bf3	C4	C1
4900	67.4	0	0.072	0.355	115.3	0.3	0.885	1	5000	2.0
3260	93.7	0	0.072	0.355	160.3	0.3	0.86	1	5000	3.0
1380	38.9	0	0.072	0.355	102.0	0.3	0.90	1	5000	3.0
2040	38.9	0	0.072	0.355	102.0	0.3	0.90	1	5000	2.6
2200	22.4	0	0.072	0.355	96.3	0.3	0.91	1	5000	2.3
2690	30.0	0	0.072	0.355	98.9	0.3	0.905	1	5000	2.2
2950	30.0	0	0.072	0.355	98.9	0.3	0.905	1	5000	2.1

Table 2-89. Calibration Constants for Wet-Warm, AC-Intermediate.

Wet-Warm, AC-Intermediate										
Long	Allig	Trans	AC Rut	Total Rut	IRI	Bf1	Bf2	Bf3	C4	C1
44200	53.8	0	0.388	0.633	110.0	0.3	0.905	1	5000	2.1
4250	14.9	0	0.388	0.633	87.0	1	0.92	1	1000	3
4950	20.7	0	0.388	0.633	89.1	1	0.91	1	1000	3
3180	36.9	0	0.388	0.633	96.8	1	0.89	1	500	3
4250	28.1	0	0.388	0.633	92.3	1	0.90	1	750	3
2650	24.2	0	0.388	0.633	90.5	1	0.905	1	500	3
3190	24.2	0	0.388	0.633	90.5	1	0.905	1	600	3

Table 2-90. Calibration Constants for Wet-Warm, AC-Thick.

Wet-Warm, AC-Thick										
Long	Allig	Trans	AC Rut	Total Rut	IRI	Bf1	Bf2	Bf3	C4	C1
750	40.8	0	0.359	0.651	141	1	0.92	1	1000	1
1040	17.9	0	0.359	0.651	130	1	0.95	1	3000	1
2910	31.6	0	0.359	0.651	136	1	0.93	1	5000	1
2810	27.5	0	0.359	0.651	134	1	0.935	1	5500	1

2.2.2 Preliminary Continuously Reinforced Concrete Pavement Calibration

The CRCP calibration was conducted prior to the flexible analysis, and the intermediate values have been lost through the passage of time. However, the calibrated and uncalibrated values are shown in Table 2-91. The Wet-Warm location did not require calibration, as the values after 30 years of traffic were satisfactory. Note that the definitions for punchouts in the SHRP manual, and used in the M-E Design Guide, describe a situation that would not be called a punchout with the TxDOT method. Figure 2-1 is the picture of punchouts found in the TxDOT distress manual, while Figure 2-2 shows a low severity punchout from the SHRP manual.

Table 2-91. Calibration Constants for CRCP.

Type	Punchouts	IRI	C3	C4	C5
Wet-Warm Default	11.4	85.4	105.263	4	-0.3816
Dry-Cold Default	55.0	173.2	105.263	4	-0.3816
Dry-Cold Calibrated	16.4	97.6	45	12	-0.5

Figure 2-1. Punchouts from TxDOT Distress Manual (TxDOT 2002).

Figure 2-2. Low Severity Punchout from SHRP Distress Manual (SHRP 1993).

2.3 RESULTS OF SINGLE VARIABLE SENSITIVITY STUDIES

The above runs were conducted and the variables that caused a significant difference were identified. Two basic methods were considered in determining how to identify whether a variable was "important." In the first method, the standard sensitivity runs were conducted and the standard deviation of the outputs was generated. Through this analysis, variables that resulted in a response more than 2.5 standard deviations from the base variable were considered significant. If more variables were included, or if different ranges were used on the variables, the standard deviations would change.

In the second method, the traffic was varied up and down by 20 percent and a variable was considered significant if by changing that value there was a difference from the base value of more than the difference caused by changing the traffic. The 20 percent value was chosen arbitrarily, but for the first set of sensitivity analysis variables it did identify almost exactly the same set of variables as the statistical method.

While the first method had some statistical validity, the second method was much more straightforward, easy to explain, and justifiable. This is the method that will be used throughout the sensitivity analysis.

A ranking method was used to classify the impact. The rank impact of changing the traffic was set to 1.0 and the inverse ratio of the impact was compared to that value. That is, a highly significant variable would have a small rank value while an insignificant variable would have a high rank value. This was done to simplify the calculations. Each variable was classified as:

- highly significant - higher impact than 20 percent traffic, ratio less than 0.5,
- significant - similar impact to traffic, ratio between 0.5 and 2.5,
- some impact - ratio greater than 2.5, but more than 0.1 percent change, and
- no impact - less than 0.1 percent change

Appendices C through N contain the results for the analysis. Each appendix has the list of highly significant and significant variables, sorted by the same category of input as was used for the description of the variables, plots of the impact of each variable, and finally tables showing the impact of each variable. In this last set of tables, the following symbols are used.

>>>	Highly significant, increasing	<<<	Highly significant, decreasing
>>	Significant, increasing	<<	Significant, decreasing
>	Some impact, increasing	<	Some impact, decreasing
=	No or little impact		

The appendices should be studied carefully, but by way of a summary, the single variable sensitivity can be condensed to Tables 2-92 to 2-94. These tables, arranged by type pf pavement, list the variables, or category of variables that were found to be the most consistently sensitive. An example of a sensitive variable category is "dates" under "General Variables." The entry means that the dates of construction for the pavement and the opening to traffic were sensitive.

The tables in the appendices also contain an asterisk alongside variables where the results of the sensitivity runs were counter to the expected performance. These may be corrected in future versions of the MEPDG.

Table 2-92. Asphalt Concrete Single Variable Sensitivity Summary.

General Variables	HMAC Variables	Base Variables	Subgrade Variables
Dates Location - Latitude - Longitude - Elevation Truck Traffic - Type - Volume	Thickness Air Voids Percent Effective Binder Thermal - Heat Capacity - Thermal Conductivity - Surface Shortwave Absorbtivity	Thickness Modulus Gradation Water Content PI Unit Weight Poisson's Ratio Hydraulic Conductivity	Thickness Modulus Gradation Classification PI Unit Weight Hydraulic Conductivity

Table 2-93. Continuously Reinforced Concrete Pavement Single Variable Sensitivity Summary.

General Variables	CRCP Variables	Base Variables	Subgrade Variables
Dates Truck Traffic - Type - Volume - Wheel Location - Wander Location - Latitude - Longitude	Thickness Steel - Percent - Diameter - Depth Strength Unit Weight Crack Spacing Thermal - Curl/Warp Temperature - Zero Stress Temperature - Coefficient of Contraction - Thermal Conductivity - Surface Shortwave Absorbtivity - Poisson's Ratio	Thickness Modulus Base/Slab Friction	Classification Modulus Water Content Water Table Depth Soil Water Values Unit Weight Poisson's Ratio

Table 2-94. Joint Plain Concrete Pavement Single Variable Sensitivity Summary.

General Variables	JPCP Variables	Base Variables	Subgrade Variables
Dates Truck Traffic - Type - Volume - Wheel Location - Wander Location - Latitude - Longitude	Joint - Spacing - LTE Strength Unit Weight Cement Type Steel - Dowels Shoulder - Type - Tied - Widened Thermal - Curl/Warp Temperature - Zero Stress Temperature - Coefficient of Contraction - Thermal Conductivity - Surface Shortwave Absorbtivity - Poisson's Ratio	Erodibility Thickness	Water Table Depth Soil Water Values

2.4 MULTIPLE VARIABLE SENSITIVITY STUDY

The M-E Design Guide is still under development and the sensitivity study was conducted with early versions of the software (versions 0.088 and mostly 0.502). Therefore, the results of this part of the project will be presented only briefly, and should be viewed with care. Other focused sensitivity studies, based on the newer version of the software (version 0.701) will be described and discussed in other sections of the report. A more complete discussion is contained in Appendix O for the analysis for AC sections, Appendix P for the CRCP, and Appendix Q has the discussion of the bonded overlay.

After the most sensitive variables were determined, a statistical design was developed to determine the impact of changing more than one variable at a time. These runs were limited to approximately 200 runs per case by eliminating non pavement-related variables (traffic wander, lane width, etc.) and grouping some of the variables, such as strength-related variables.

2.4.1 Factorial Design for Multiple Variable Analysis

The list of variables that had a significant effect were tabulated and grouped. Table 2-95 contains the inital list of (practically) significant factors selected in the initial runs.

Table 2-95. Factors for Dry-Cold, AC-Thin.

Factor #	Factor	Level	
1	Construction Time	-2 Months	+2 Months
2	Road Type	Local	Minor
3	AADT	-20%	+20%
4	Elevation	-1500	+1500
5	AC Thick	-0.5"	+0.5"
6	AC PG Grade	58-34	76-22
7	AC Air Voids	-1.7	+3.8
8	AC Eff Binder	-3%	+3%
9	AC Heat Capacity	+0.8	+0.17
10	AC Poisson's Ratio	-0.05	+0.05
11	AC Dynamic Mod	/1.5	×1.5
12	CS Soil Water Value	Low	High
13	Crushed Stone Thick	-1.0"	+1.0"
14	CS Poisson's ratio	-0.05	+0.05
15	CS Resilient Modulus	/2	×2
16	CHLS D60	/4	×2
17	CHLS Soil Water Value	Low	High
18	CHLS P200	-10%	+70%
19	CHLS Resilient Mod	×0.7	×1.3
20	SG PI	-10	+10
21	SG Unit Wt	-11	+9
22	SG Resilient Modulus	-5k	+5k
23	SG Thickness	-25	+25

The full factorial design containing all possible combinations of the factor levels listed in the above table requires 1,048,576 runs. The full factorial design would have been needed if we are interested in all higher-order interactions. In practice, interactions higher than two-way interactions are often negligible, and estimating the main effects and the two-way interactions is of practical interest. Thus, the size of the design can be reduced by selecting the factor-level combinations that allow estimation of all the main effects and the two-way interaction effects only. The minimum number of runs required to estimate all the main effects and the two-way interaction effects (obtained by a D-optimal design) turns out to be 277.

This number of runs was still considered to be too many, as each run takes 30 to 45 minutes. It was necessary to further screen the number of the important factors (8 to 11) from Table 2-95 by a screening design, and then generate a fractional factorial design that can estimate all the main effects and the two-way interactions based on those selected factors. A screening design consisting of only 28 runs was generated. Once the subset of factors was selected by running this experiment, a fractional factorial design with a moderate number of runs could be generated. Table 2-96 shows the number of runs for a fractional factorial design to estimate all the main effects and two-way interaction effects when the number of selected factors by the screening design is 8, 9, 10, 11, or 12.

Table 2-96. Number of Runs for a Fractional Factorial Design to Estimate All Main Effects and Two-way Interaction Effects.

Number of Factors	Number of Runs
8	64
9	128
10	128
11	128
12	256

Alternatively, a D-optimal design with a minimum number of runs required to estimate all the main effects and the two-way interaction effect can be considered. Table 2-97 shows the minimum number of runs for a D-optimal design to estimate all the main effects and two-way interaction effects when the number of selected factors by the screening design is 8, 9, 10, 11, 12, 13, 14, 15, 16, or 17. Note that the number of runs in Table 2-97 is the minimum number of runs for D-optimal designs, and the precision of the estimates will be lower than those from the fractional factorial designs or D-optimal designs with higher (default) number of runs.

The final decision was to use the D-optimal design, which would help reduce the number of runs, and limit the number of runs to about 200 runs per case. Appendices O, P, and Q contain the list of variables selected and the results of the multi-variable analysis.

Table 2-97. Minimum Number of Runs for a D-optimal Design to Estimate All Main Effects and Two-way Interaction Effects.

Number of Factors	Minimum Number of Runs
8	37 (64)
9	46 (64)
10	56 (64)
11	67 (128)
12	79 (128)
13	92 (128)
14	106 (128)
15	121 (128)
16	137 (256)
17	154 (256)

Note: The numbers in parentheses after the minimum numbers of runs are the default numbers of runs for D-optimal designs.

CHAPTER 3 - REVIEW OF CURRENT DESIGN PROCEDURE AND PRELIMINARY CALIBRATION OF THE GUIDE

3.1 REVIEW OF THE CURRENT ASPHALT PAVEMENT DESIGN PROCEDURES

The following presents a review of the design procedures developed by TTI for TxDOT, since 1968.

3.1.1 FPS11

FPS11 is based on the equations derived by Scrivner et al., 1968. The loss in serviceability, Q_2, during a period of time (season), due to 18 kip SA load applications (N_2-N_1) is defined as:

$$Q_2 = \sqrt{5-P_2} - \sqrt{5-P_1} = \frac{53.6 \cdot (N_2 - N_1) \cdot S^2}{\bar{\alpha}} \tag{1}$$

where

P_2 = Serviceability at the end of the period

P_1 = Serviceability at the beginning of the period

S = Surface curvature index (SCI) determined by the dynaflect, in mils

$\bar{\alpha}$ = Harmonic mean of the daily temperature values of α existing during the period (ºF)

α = Mean daily air temperature minus 32 ºF.

Additional terms for serviceability loss are included for the effect of swelling clay. The derivation of Equation 1 is based on limited analyses of AASHO road test results. Therefore, FPS11 and the updated versions are empirical design methods, as are all previous versions of the AASHTO Guide. Because the traffic composition and level have changed since the development of the method, it is not clear whether the method is still adequate, should be re-calibrated, or completely replaced.

The surface curvature of the pavement, which characterizes the pavement strength, is estimated using the layer thicknesses, D_i, and their stiffness coefficients, a_i (different from the AASHTO layer coefficients). A method similar to the method of equivalent thickness (MET) was used to compute S in a system of n layers. Therefore, the stiffness of the layers can be varied with seasons. The performance of the pavement is simulated by solving Equation 1 for P_2, for all the seasons, in the order of appearance during the design period. The stiffness coefficients were backcalculated from deflection bowl measurements in the field. All local/conventional materials had their stiffness coefficients tabulated. Table 3-1 presents a summary of the values calculated by Scrivner et al. (1968). The stiffness coefficient of asphaltic material is given by the following equation:

$$a_1 = 0.52 + 0.00284(62 - T) \tag{2}$$

where T is the mean daily temperature, in °F.

It should be noted that:

- According to Scrivner and Michalak (1969): "The critical wheel load stress acting in the pavement structure, particularly the tensile stress acting at the bottom of the asphaltic concrete layer, is believed to be approximately proportional to the curvature of the surface produced by the load." It seems that the design is more fatigue oriented than permanent deformation oriented.

- The stiffness coefficient of the asphalt concrete (Equation 2) is only slightly higher than that of granular bases (Table 3-1). The contribution of the AC layers to the overall stiffness is not much different than that of the granular base materials. In the life-cycle cost analysis, this and the fact that thinner asphalt layers are more "fatigue resistant" will produce designs with thin AC layers.

- The method is based on only one parameter, the surface curvature, for characterizing the subgrade and the pavement altogether, and for preventing all types of distress (both cracking and rutting).

Table 3-1. Stiffness Coefficients for FPS11.

Layer	Description	Average Stiffness Coefficient
Subgrade	Red Sandy Clay	0.222
	Silty Black Clay	0.223
	Brown Clay	0.227
	Tan Sandy Clay	0.233
	Black Clay	0.239
	Gray Sandy Clay	0.240
	Brown Sandy Clay	0.241
	Sand and Clay	0.258
	Gray and Brown Sand	0.259
Base	Sandstone	0.388
	Red Sandy Gravel	0.514
	Mixture (Base and Subbase)	0.521
	Mixture (Base and Subbase)	0.708
	Lime Stabilized Sandstone	0.609
	Asphalt Stab. Gravel	0.631
	Iron Ore Gravel	0.691
	Cement Stab. Limestone	0.877
	Asphalt Emulsion Stab. Gravel	0.882

In summary, FPS11 was developed in 1968 for relatively light traffic. It is based on SCI, which is fatigue oriented. This may explain why FPS11 produced designs with relatively thin

AC layers. The extension of the use of this program to medium and heavy traffic loads may require a revision of the approach and calibration.

3.1.2 TFPS

The Texas Flexible Pavement System (TFPS) was a 5 year effort to develop a mechanistic-empirical design method for flexible pavements (Uzan et al. 1991). Models were developed to predict pavement life using three basic failure modes, or measures of pavement deterioration: fatigue cracking, rutting, and pavement roughness. During the pavement design life, several combinations of pavement layer thicknesses and failure conditions can be considered by the design program as well as select, on an economical basis, the most suitable structures for the given conditions. The program also considers damage due to swelling soils, as well as longitudinal and transversal cracking. The TFPS program included:

- environmental conditions for all Texas districts/counties,
- mechanistic subsystems for fatigue cracking and rutting caused by traffic loads,
- empirical equations for the prediction of pavement roughness as a function of traffic and material properties,
- multiple overlays, and
- reliability analyses based on the variability of the input variables.

The report stated: “Implementation of the design program should be accompanied with further training seminars and design schools oriented towards increasing the understanding of the use of the design program.” These recommendations were never implemented and the decision was made to upgrade FPS11 into FPS19W instead. According to Scullion and Michalak (1997), “TFPS provided many important upgrades to the existing modeling capabilities and offered great potential for future development. However TxDOT decided that the new system was not ready for full-scale implementation. It was concluded that the mechanistic empirical procedures could not adequately handle the vast array of material types and pavement structures designed by TxDOT….”

In essence, the M-E Design Guide uses an approach similar to that developed under TFPS. As stated by the NCHRP 1-37A team, training is the key issue for the implementation of the Guide.

3.1.3 FPS19

FPS19 is a new version of FPS11 (Scullion and Michalak, 1997) where the SCI is computed using the computer program WESLEA for linear elastic multilayer systems. The user enters the moduli of the different materials, based on backcalculation and analyses of deflection bowls from falling weight deflectometer (FWD) testing. The program recommends MODULUS 5.1 for backcalculation of the layer moduli. For conventional flexible pavements (HMAC over flexible base on top of the subgrade), the modulus of granular materials above the subgrade is computed using the following equation (from the U.S. Army Corps of Engineers):

$$E_B = E_S(1 + 9.07 \log h_B - 1.85 \log h_B \log E_S) \tag{3}$$

where

E_B = Modulus of the base material (psi)
E_S = Modulus of subgrade (psi)
h_B = Thickness of the base layer (in.), up to 10 inches

Moreover, the computed SCI is corrected for the difference between deflections recorded by a falling weight deflectometer (FWD) and the deflections produced by truck types of loadings and for vehicle speed. In addition to this analysis, a Texas Triaxial Design check is performed. The user can also perform a an optional emperical-mechanistic design check using models from a variety of agencies. FPS19 was checked to give results similar to FPS11 but not calibrated against field sections. FPS19W is the Windows® based version of FPS19.

3.1.4 Discussion

In the current state of knowledge in the fields of materials and pavement design, it is logical to ask: Is one parameter (SCI) capable of producing reliable flexible pavement design, for a diversity of materials, environmental and traffic conditions? Can the SCI protect against fatigue cracking, longitudinal cracking, and permanent deformation?

Any pavement design system (FPS19W, M-E Design Guide, or other) is based on transfer functions that are applied to computed responses to traffic loading. The reliability of the design will depend on these computations, which depend on the input data. Usually the transfer functions are “calibrated” for the particular set of input data, to give predicted performance similar to that observed. Therefore, the whole process depends on the input data. One set of input data may be adequate for one set of transfer functions (for example, in the Guide); however, it may not be adequate for a different set of transfer functions (e.g., FPS19W or other). This limitation should be reduced and hopefully eliminated as the design becomes more rational and as material properties are better defined.

3.1.5 Checking Calibration of FPS19W and the M-E Design Guide

The design obtained from using the FPS19W program on the LTPP data for general pavement studies (GPS) sections will be compared to that obtained with the M-E Design Guide and the actual performance of the GPS sections. Table 3-2 presents a summary of the input variables in terms of thicknesses and elastic moduli. These variables and other input variables necessary for running the Guide were taken from “Appendix EE: Calibration Sections for Flexible Pavements” (2002 Design Guide [2004]).

The pavement sections were run using the M-E Design Guide with Level 3 data. For simplification, the moduli of the unbound materials were kept constant, unaffected by EICM during the years of analyses. Moreover, the traffic used was expressed in terms of 18 kip ESALs for both the M-E Design Guide and FPS19W.

Table 3-2. Summary of Input Variables (Thickness in Inches, Moduli in psi).

Site	Years of Traffic	20 Year 18 kip ESALs $\times10^6$	AC Layer Thickness	Base Layer Thickness/ Modulus	Subbase Layer Thickness/ Modulus	Subgrade Layer Modulus
480001	10	2	1.2 + 1.4	14.7 38,000	-	17,000
481060	13	3	1.7 + 5.8	12.3 40,000	6 38,000	32,000
481077	17	3.6	1.4 + 3.7	10.4 40,000	-	24,000
481109	15	2.8	1.1 + 5.4	-	-	24,000
481130	27	0.8	2.7	17.9 40,000	8 20,000	8,000
481169	27	1.8	1.9	11.3 32,000	-	29,000
481174	24	1.4	1.4 + 3.3	13.2 40,000	-	8,000
481178	11	1.3	2.1 + 6.4	10.8 38,000	-	8,000
481183	24	1.6	1.3 + 4.4	-	-	17,000
483749	18	1.8	1.8	8.1 38,000	-	8,000
489005	13	0.46	1.5	9.4 24,000	-	8,000

3.1.6 FPS19W Calibration Results

The results obtained from using the FPS19W program on the data are summarized in Table 3-3. The results are expressed in terms of design life that the pavement structure can serve for the given traffic conditions. Also included in Table 3-3 are the distresses estimated at the end of the years of traffic, taken from Appendix EE: Calibration Sections for Flexible Pavements (2002 Design Guide [2004]). The evaluation of the results is presented in the comment column. Note that 5 of the 11 sections are adequate, 2 are under-designed, and 4 are over-designed. For example, section 481130 is shown to have 40 years of design life (FPS19W prediction); however, it has already exhibited 0.7 inch rut depth after only 27 years of traffic. Therefore, this section is considered as under-designed by FPS19W. It is worth mentioning that over-predicting a pavement life by a factor of 3 is not unusual in pavement design, especially when a high level of reliability is used. The number of under-design cases (more than 20 percent) indicates that FPS19W needs to be calibrated more closely.

Table 3-3. Summary of Results Obtained Using FPS19W.

GPS Site	Years of Traffic	FPS19W Life (years)	Longitudinal Crack (ft/mi) Measured	Alligator Crack (percent) Measured	Rutting (in.), Measured	Comments
480001	10	22	45	<1	0.3	Adequate
481060	13	40	58	<1	0.35	Adequate
481077	17	12	350	<1	0.73	Good
481109	15	28	900	<1	0.4	Adequate
481130	27	40	40	~2	0.7	Under-design
481169	27	9	<10	~1	0.45	Over-design
481174	24	40	290	~1	0.6	Under-design
481178	11	40	110	<1	0.25	Adequate
481183	24	13	22	<1	0.3	Over-design
483749	18	5	50	16	0.5	Over-design
489005	13	13	400	<1	0.22	Over-design

3.1.7 M-E Design Guide Calibration Results

Table 3-4 presents a comparison of predicted distresses using the M-E Design Guide and observed distresses from the measurements. Figure 3-1a presents a comparison of the predicted versus measured rut depth. Note that the rut depths are distributed around the line of equality (dashed line) and that the equation for the regression has a coefficient very close to 1.0 (1.040), indicating that the model is adequate. If section 481077 is removed (measured 0.73, predicted 0.39), the predicted rut depths are larger than the measured values (slope = 1.18). If section 489005 is removed (measured 0.22, predicted 0.57), the equation improves (slope = 1.009).

Figure 3-1b presents a comparison of the predicted versus measured longitudinal cracking at the surface. Note that the longitudinal cracking values are distributed around the line of equality and that the equation for the regression has a coefficient very close to 1.0 (1.0758), indicating that the model is adequate The scatter is quite large; however, the crack at the surface may not be deep. The Guide seems to over-predict the alligator cracking. In fact, among the 11 sections used in the calibration, only one (section 483749) had a substantial amount of fatigue cracking, and it was predicted fairly closely. Based on the 11 sections and for the 18 kip ESAL traffic load, the Guide seems to predict the observed distresses quite well.

Table 3-5 presents the results of analyses using truck traffic classification (TTC). Average annual daily truck traffic was extracted from LTPP records and entered in the M-E Design Guide. The material properties were kept as above in the FPS19W analysis. It is seen that all distresses are over-predicted. This may be due to the axle load distribution or to the transfer functions used in the Guide. These axle load and transfer functions do not seem to lead to the same ESAL as obtained from the AASHO Road Test. This result points to the fact that before it can be implemented, local calibration of the Guide is mandatory.

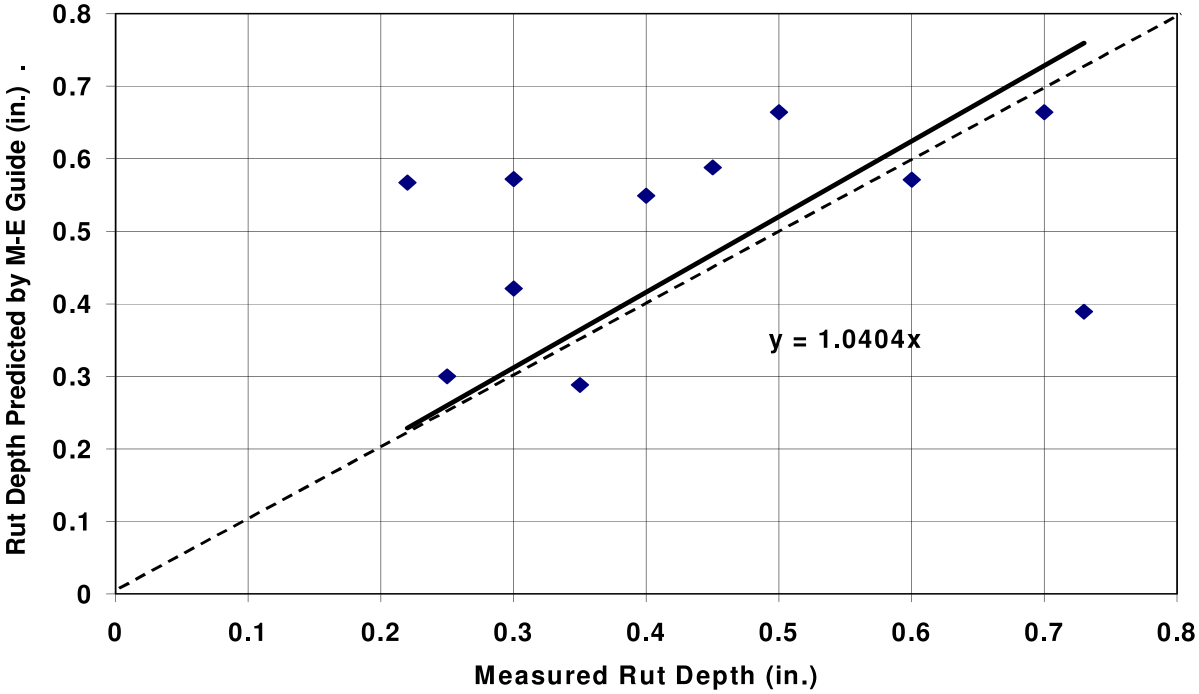


Figure 3-1a. Comparison of the M-E Design Guide Predicted vs. Measured Rut Depths.

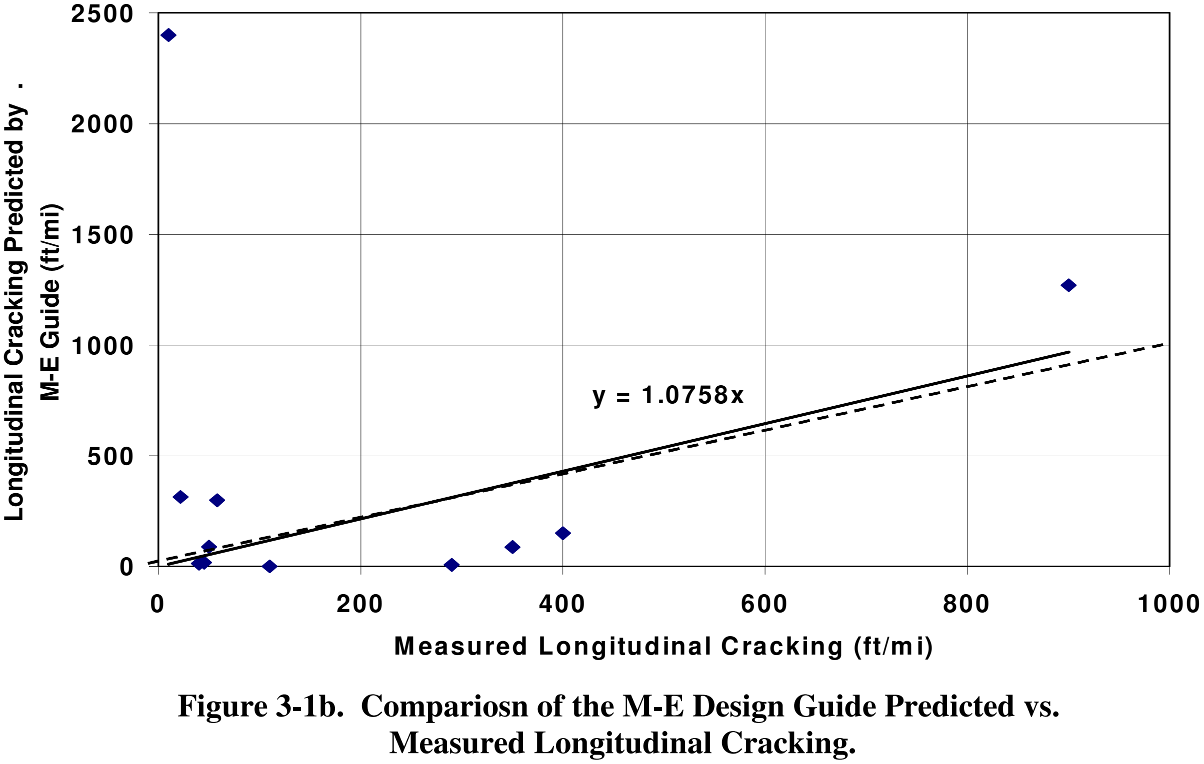


Figure 3-1b. Compariosn of the M-E Design Guide Predicted vs. Measured Longitudinal Cracking.

Table 3-4. Summary of Results Obtained Using M-E Design Guide and 18 Kip ESAL.

Site	Years of Traffic	Rutting (in.)		Alligator Cracking (percent)		Longitudinal Cracking (ft/mi)	
		Predicted by Guide	Measured	Predicted by Guide	Measured	Predicted by Guide	Measured
480001	10	0.572	0.30	6.1	<1	16.7	45
481060	13	0.288	0.35	2.5	<1	299.0	58
481077	17	0.389	0.73	3.4	<1	87.5	350
481109	15	0.549	0.40	5.3	<1	1270.0	900
481130	27	0.664	0.70	11.8	~2	12.3	40
481169	27	0.588	0.45	16.2	~1	2400.0	<10
481174	24	0.571	0.60	25.6	~1	6.9	290
481178	11	0.300	0.25	0.1	<1	0.2	110
481183	24	0.421	0.30	7.5	<1	314.0	22
483749	18	0.664	0.50	16.5	16	88.9	50
489005	13	0.567	0.22	8.1	<1	150.0	400

Table 3-5. Summary of Results Obtained Using M-E Design Guide and Default Truck Traffic Class (Before Calibration).

Site	Years of Traffic	TTC	AADTT	AADTT Growth	Rutting (in.)		Alligator Cracking (percent)		Longitudinal Cracking (ft/mi)	
		Functional Class	Trucks /Day	(Linear Percent)	Predicted by Guide	Measured	Predicted by Guide	Measured	Predicted by Guide	Measured
480001	10	11	321	56.0	1.171	0.30	49.8	<1	187	45
481060	13	2	278	65.0	0.556	0.35	9.8	<1	9840	58
481077	17	2	488	8.8	0.594	0.73	8.0	<1	3860	350
481109	15	2	450	0.0	0.757	0.40	8.2	<1	9400	900
481130	27	6	109	4.7	0.922	0.70	23.8	~2	19.3	40
481169	27	6	177	5.0	0.729	0.45	26.6	~1	3090	<10
481174	24	2	282	0.0	0.839	0.60	42.5	~1	170	290
481178	11	2	180	30.6	0.561	0.25	0.4	<1	13.1	110
481183	24	2	400	0.0	0.711	0.30	18.7	<1	8570	22
483749	18	2	318	0.0	0.887	0.50	38.0	16	182	50
489005	13	8	105	0.0	0.811	0.22	43.4	<1	429	400

Prior to calibration, a critical review of the material properties, layer thicknesses, and distress surveys should be made for all sites being used in the calibration. For a few of the cases, trenches should be cut through the pavement for the purpose of estimating the contribution of each layer to rutting. This is crucial for calibrating the rutting models of the different materials (subgrade soils, granular bases, and AC).

3.1.8 Preliminary M-E Design Guide Calibration

A preliminary calibration was attempted using the results of the above LTPP GPS sections. Figure 3-2 presents the measured and the computed (total and in the AC layer) rut depths from the M-E Guide as a function of the AC layer thickness. It shows that:

- The predicted total rut depth is much larger than the measured rut depth.
- The predicted rut depth in the AC layer is very nearly equal to the measured rut depth.

Note also in Figure 3-2 that the contribution of the unbound layers (base, subbase, and subgrade), the difference between predicted total rutting and rutting in the AC layer, becomes smaller as the AC layer thickness increases. The computed total rut depth is about 40 percent larger than the measured value. Since there were few or no trenches and associated laboratory tests available for conducting a calibration in a rational manner, and in order to keep intact the trends of the national calibration, only a few, basic factors were changed. Therefore, the rutting in the AC layer was reduced by a factor of 0.7 ($\beta_{r1} = 0.7$ in the calibration settings). In order to bring the total rutting more in line with the measured values, the contribution of the unbound layers was reduced by a factor of 0.6 ($\beta_{s1} = 0.6$ in the calibration settings). The factors of 0.7 and 0.6 were chosen to reduce the rutting by 0.65 and only for illustration purposes of the calibration procedure. As for the alligator and longitudinal cracking, changing just one calibration factor reduced the over-predicted amounts of cracking. The C_1 factors in the calibration settings were changed as follows: C_1(bottom) = 1.2 (from 1) and C_1(top) = 9 (from 7). This corresponds to a translation of the sigmoidal curves used for computing the cracked area as a function of the damage. The results of the new runs are summarized in Table 3-6 and Figures 3-3a and 3-3b. The new computed values of the rut depth and longitudinal cracking fit the measured ones better. The scatter is still large, possibly due to inappropriate description of the structure or material properties. It is possible that the fit could be improved by changing some other calibration factors, but more data are needed.

The number of calibration factors is relatively large, giving the possibility to fit the field distresses to the computed ones. However, as stated before, the materials properties entered in the analysis need also to represent actual materials in the structure. This is especially true for TxDOT, which has its own material specifications. The NCHRP 1-40B project will provide guidance on how to make local calibration.

The following conclusions were drawn from the study presented in this chapter:

- The current design method (FPS19W) is an extension of the old FPS11 empirical pavement design program.
- FPS19W needs to be calibrated. Materials, pavements, and traffic have all changed considerably since FPS11 was developed.
- The Guide is a mechanistic-empirical method, which also needs to be locally calibrated.
- If used uncalibrated, rutting, alligator cracking, and longitudinal cracking will be over-predicted and the design will be conservative.

- Because TxDOT has specific material specifications and uses materials not found in the M-E Design Guide, the materials need to be characterized before any calibration can be attempted.

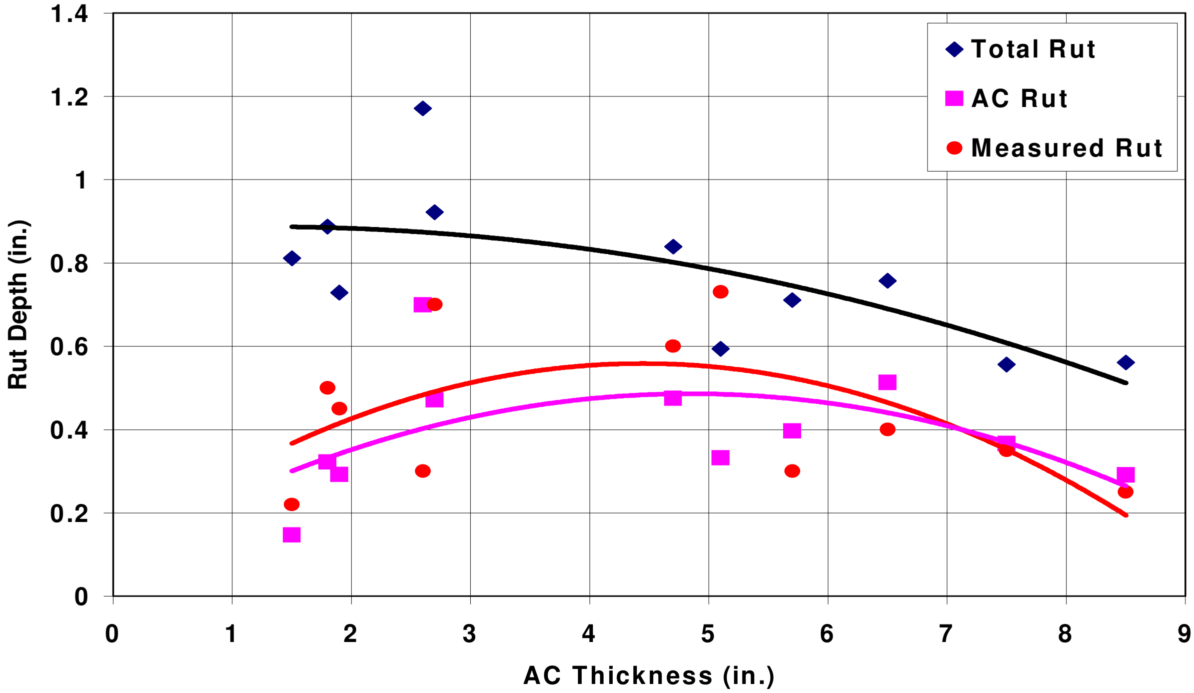


Figure 3-2. Comparison of the Measured and M-E Design Guide Computed Rut Depth vs. Layer Thickness.

Table 3-6. Summary of Results Obtained Using M-E Design Guide and Default Truck Traffic Class (After Calibration).

		TTC	AADTT	AADTT Growth	Rutting (in.)		Alligator Cracking (percent)		Longitudinal Cracking, ft/mi	
GPS Site	Years of Traffic	Functional Class	Trucks /Day	(Linear percent)	Predicted by Guide	Measured	Predicted by Guide	Measured	Predicted by Guide	Measured
480001	10	11	321	56	0.773	0.3	2.0	<1	3	45
481060	13	2	278	65	0.370	0.35	0.4	<1	686	58
481077	17	2	488	8.8	0.390	0.73	2.9	<1	765	350
481109	15	2	450	0	0.505	0.4	0.3	<1	552	900
481130	27	6	109	4.7	0.600	0.7	7.6	~2	3	40
481169	27	6	177	5	0.467	0.45	4.2	~1	560	<10
481174	24	2	282	0	0.551	0.6	20.1	~1	23	290
481178	11	2	180	30.6	0.366	0.25	0.1	<1	2	110
481183	24	2	400	0	0.467	0.3	7.6	<1	390	22
483749	18	2	318	0	0.565	0.5	9.2	16	25	50
489005	13	8	105	0	0.501	0.22	8.4	<1	60	400

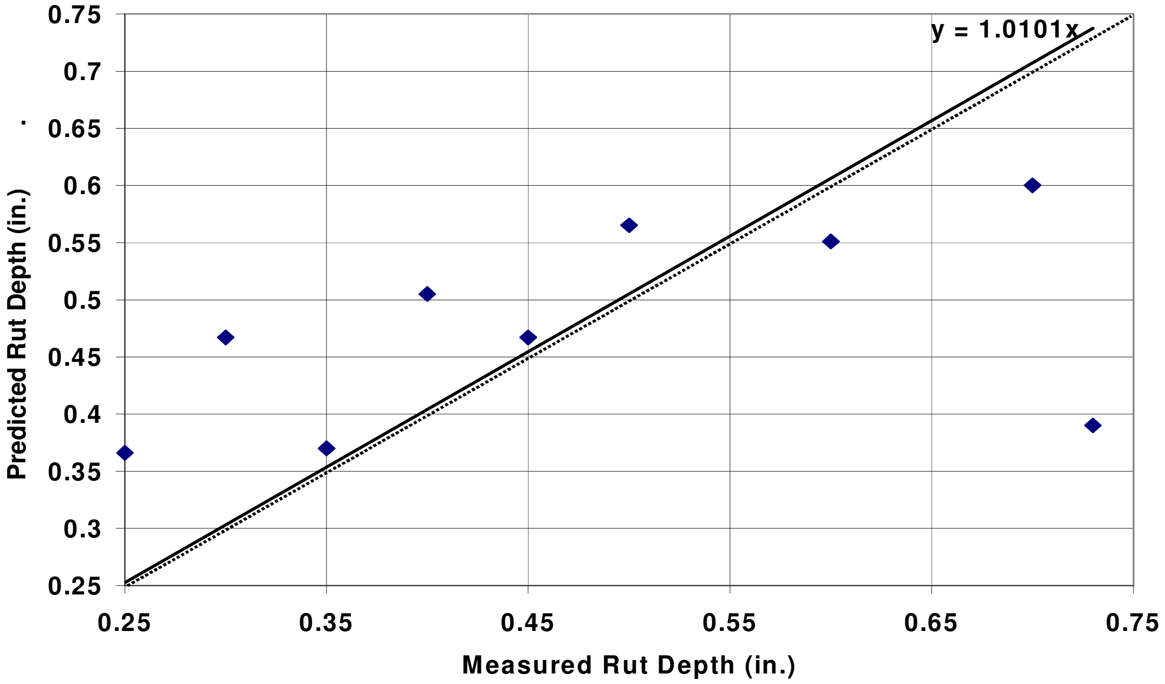


Figure 3-3a. Calibrated Predicted Rut Depth vs. Measured Rut Depth.

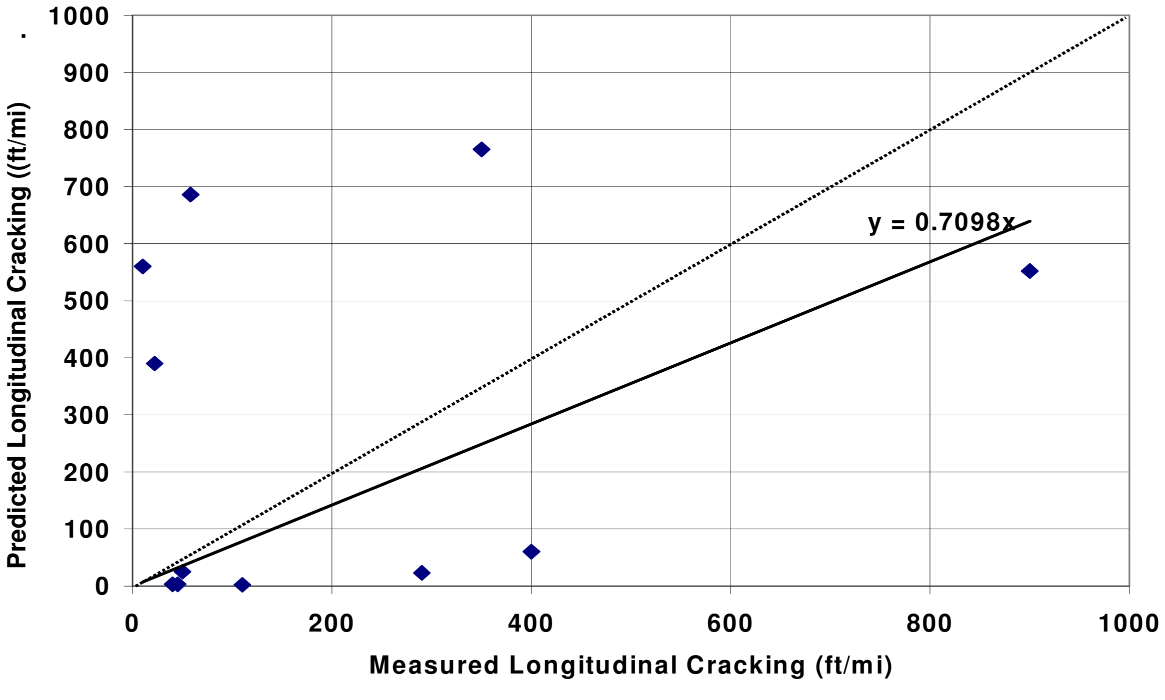


Figure 3-3b. Calibrated Predicted Longitudinal Cracking vs. Measured Longitudinal Cracking.

3.1.10 Review of Existing Perpetual Pavement Designs in Texas

In April 2001, TxDOT issued a memorandum for designing pavements when the design life of the pavement exceeds 30 million ESALs (one way per roadbed). Two new AC mixes (the heavy duty stone matrix asphalt – HDSMA and stone filled hot mix asphaltic concrete pavement – SFHMACP) were introduced to be used solely on these types of pavements. The pavement structure was subdivided into four sublayers as shown in Figures 3-4a and 3-4b. The top layer is designed to be both rut and wear resistant. Figure 3-4b includes both the porous friction course and the HDSMA layer. The intermediate AC layer is rut resistant and is composed of SFHMACP. In Figure 3-4b, this layer is further reduced into a transitional and load carrying layers. The last (bottom) AC layer is fatigue resistant. In Figure 3-4b, it is specified to have only 2 to 3 percent air voids. The full-depth pavement is constructed either on a stiff base or on a stabilized subgrade. No special directives are given on how to compute the pavement thickness, except for the recommended layer thicknesses shown in Figures 3-4a and 3-4b.

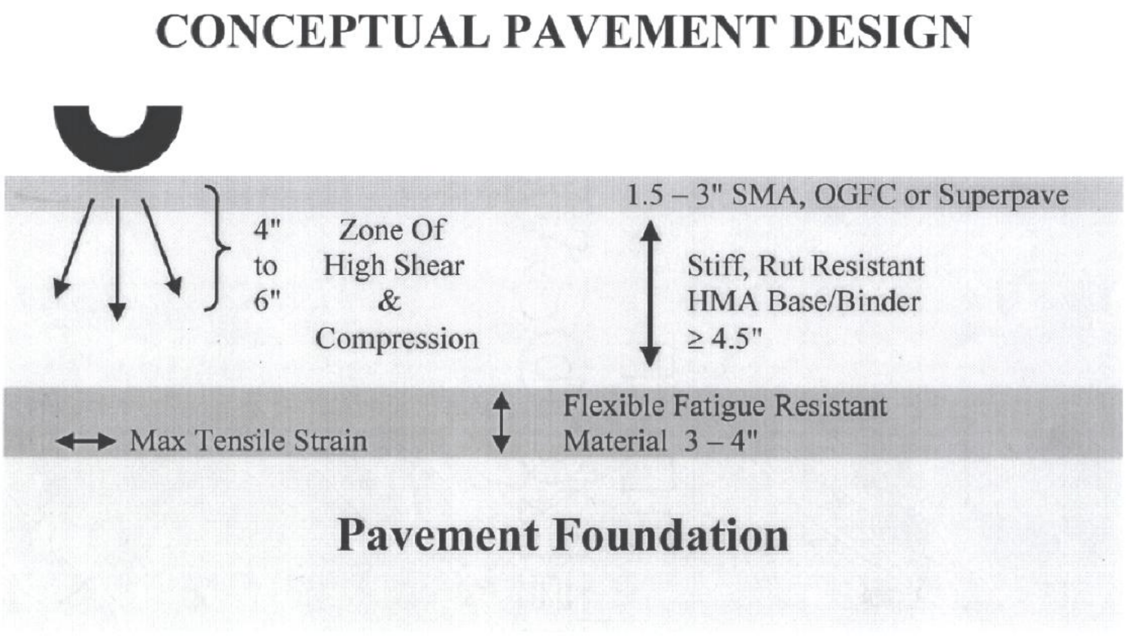


Figure 3-4a. TxDOT Perpetual Pavement Layout.

PROPOSED STRUCTURAL SECTIONS

NEW CONSTRUCTION

PFC (SS3231)	1.0" to 1.5" Porous Friction Course	(Sacrificial Layer)
HDSMA (SS3248)	2.0" to 3.0" Heavy Duty SMA ½" Aggregate with PG 76-XX	(Impermeable Load Carrying Layer)
SFHMAC (SS3249)	2.0" to 3.0" Stone Filled HMAC ¾" Aggregate with PG 76-XX	(Transitional Layer)
SFHMAC (SS3248)	8.0" to 'Variable' Stone Filled or CMHB 1.0" or 1.5" Aggregate with PG 76-XX	(Load Carrying Layer)
SUPERPAVE (SS3241)	2.0" to 3.0" SuperPave or 3146 ½" Aggregate with PG 64-XX Target Lab Molded Density 98.0% (2-3% Rdwy Air Voids)	(Stress Relieving Impermeable Layer)
Stabilized Foundation	6.0" to 8.0" Stiff Base or Stabilized Subgrade Primarily to serve as construction working table or compaction platform for succeeding layers.	

Figure 3-4b. TxDOT Perpetual Pavement Layer Designations.

3.2 M-E DESIGN GUIDE PERFORMANCE RELATED CRITERIA FOR THE DESIGN OF CRC PAVEMENT SYSTEMS

As previously noted, the potential for punchouts may be greater in cases where combinations of short and long crack spacings occur and the loss of shear capacity is excessive. However, CRC pavements with predominantly short crack spacing do not necessarily dictate that poor performance will be the end result, particularly where the support conditions are good and design thickness is adequate. As suggested in the previous equations, combinations of crack spacing and slab thickness can assure proper levels of stiffness at the transverse cracks in a CRC pavement.

In CRC pavement systems, good performance goes hand in hand with adequate stiffness at the transverse cracks. This cannot only be assured through adequate crack width/thickness combinations, but also through uniform crack opening and crack space distribution, in addition to the provision of uniform support conditions throughout the life of the pavement. Steel reinforcement also serves to sustain the stiffness of the transverse cracks through crack width as it may be affected by the crack spacing, which is influenced by temperature drop and drying shrinkage. The procedure outlined in Appendix A serves to generate steel percentage − crack width relationships for different reinforcement bar sizes and configurations. Figure 3-5 shows maximum crack width for a given slab thickness to provide sufficient stiffness to prevent aggregate wear-out. This figure demonstrates crack width requirements relative to slab thickness and load transfer requirements. Note that the limits shown in Figure 3-5 fall between those recommended by Permanent International Association of Roads Congresses (PIARC) (0.5 mm [20 mils]) (PIARC 1994) and those recommended by AASHTO (1 mm [40 mils]) (AASHTO 1993). The data trends in Figure 3-6 illustrate how loss of shear capacity may vary with crack width and load transfer efficiency. The trends also suggest that the PIARC requirements for crack width are too conservative and do not allow for loss of shear capacity as it would pertain for typical CRC pavement thickness design. From the steel percentage – crack width relationships and a given design slab thickness, a maximum crack width can be associated with a selected design steel percentage.

3.2.1 Comparability to AASHTO 93

Comparisons between predicted cracking from the M-E Design Guide and AASHTO 1993 programs, shown in Figures 3-7 and 3-8, are based on the following factors:

- percent steel (0.4, 0.6, and 0.8 percent);
- bar size (#5 and #6 bars);
- drying shrinkage (315 and 458 microstrain);
- assumed temperature drop of 55 ºF; and
- concrete strength of 4500 psi, tensile strength of 460 psi.

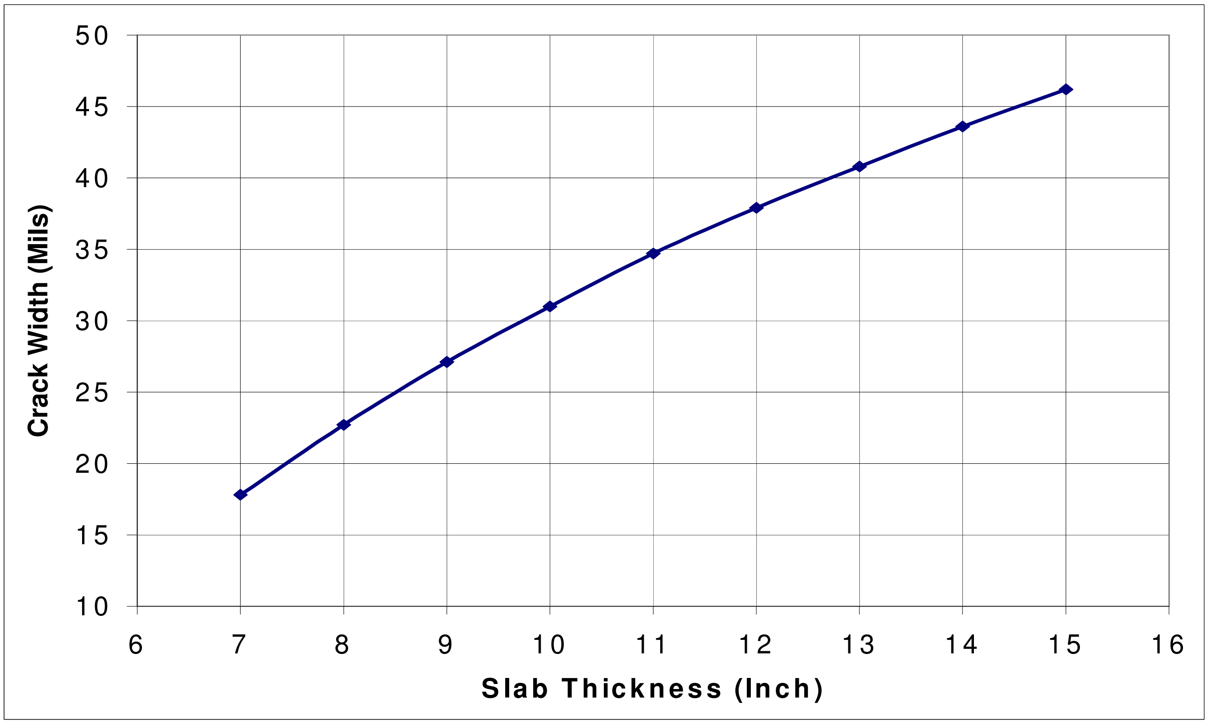


Figure 3-5. Crack Width – Thickness Combination to Achieve 91% Load Transfer Efficiency (Jeong et al. 2001).

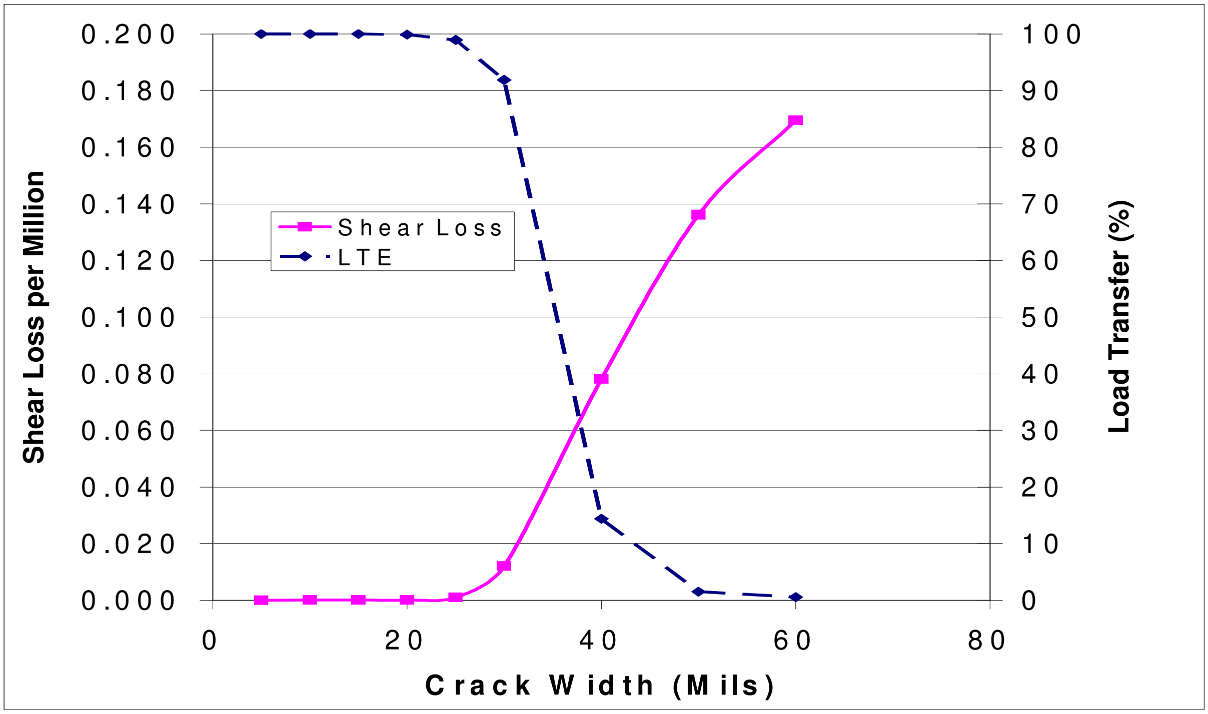


Figure 3-6. Relationship Between LTE and Loss of Shear Capacity.

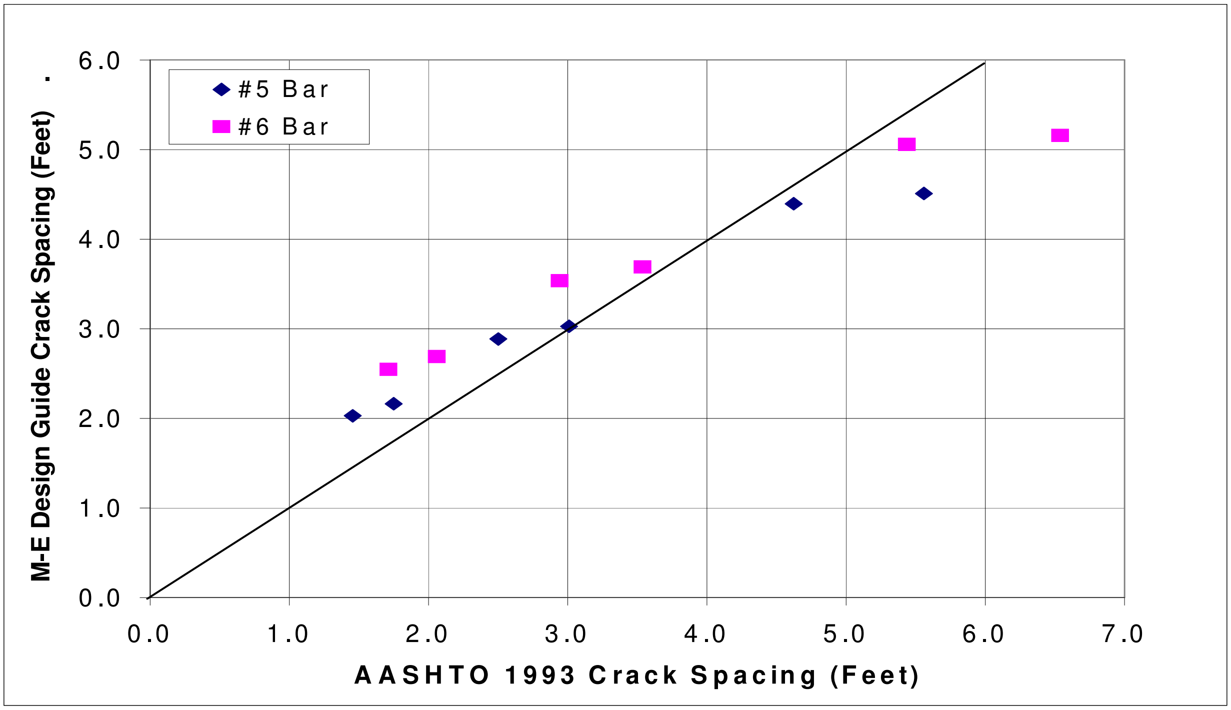


Figure 3-7. Comparison of Cracking Intervals for AASHTO 1993 and M-E Design Guide.

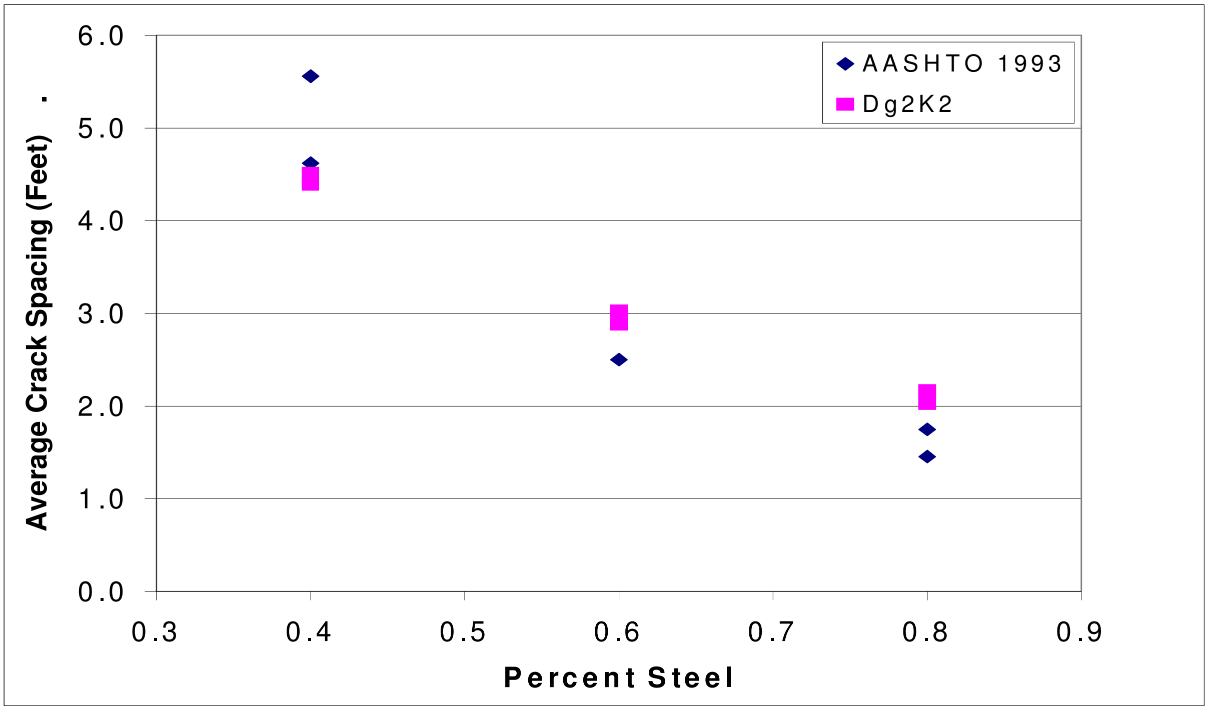


Figure 3-8. Comparison of Cracking vs. Steel Content Between AASHTO 1993 and M-E Design Guide.

3.2.2 Summary of Comparisons for CRC Design

The comparison shown in Figure 3-7 is made at three different steel contents and two different rebar sizes between the two methods of design and appears to be reasonable over the ranges of cracking intervals as shown. However, the M-E Design Guide considers the stress from the applied wheel load in the total cracking stress. The wheel load stress used for the above comparison was 120 psi, which is a reasonable estimate of the longitudinal wheel load stresses. It was assumed that the AASHTO 1993 program is based on a temperature drop of 55 ºF where the resulting temperature related strain was added in the shrinkage strains noted above in the determination of the M-E Design Guide crack spacing. Concrete strengths in the M-E Design Guide are correlated to compressive strength and the comparisons are limited by that relationship. The comparison can also be made over the range of steel percentages and again the comparison is reasonable as shown in Figure 3-8.

CHAPTER 4 - FOCUSED SENSITIVITY STUDIES AND AREAS OF INTEREST

In this chapter, several specific areas of interest in the M-E Guide were investigated including factors affecting CRCP design and environmental effects for HMAC pavements including the selection of weather stations, depth to water table, and thermal cracking.

4.1 AREAS OF INTEREST IN CRCP DESIGN

The following discussion uses the results of the M-E Design Guide analysis on specific areas relating to the design of CRCP; specifically, the use of the groups of variables that control the crack spacing and load transfer efficiency. These clusters combine with the traffic cluster to control and determine the punchouts on CRCP.

4.1.1 Cracking Cluster

The cracking cluster is the ratio of the crack spacing in CRC pavement to the radius of relative stiffness (rrs):

$$= \frac{CrackSpacing}{rrs}; rrs = \sqrt[4]{\frac{E_e^3}{12(1-v^2)k}}$$

Crack spacing is a performance related parameter because of its correlation to crack width of the transverse cracks, which plays a key role in the performance of a CRC pavement. Typically, the larger the spacing the wider the crack widths and the greater the rate of punchouts. The rrs, also referred to as the ℓ-value, is an important parameter in the analysis of concrete pavement systems that is often related to their cracking performance. The factors included in the equation of rrs are listed as:

E = Concrete modulus (from 3×10^6 to 5×10^6)
h_e = Effective slab thickness (L)
$= \sqrt[3]{h^3 + \frac{E_b}{E_c} h_b^3}$ (for unbonded conditions between the slab and the subbase)
h = Slab thickness (from 10 to 15 in.)
h_b = Subbase thickness (from 4 to 6 in.)
υ = Poisson's ratio (from 0.15 to 0.20)
k = Foundation modulus (80 to 250 psi/in. – static subgrade value)
E_b = Subbase modulus (50,000 to 1×10^6 psi)

Crack spacing is included in the above cluster, and in a CRC pavement system the following factors have been noted to affect it:

- steel cover (ζ),
- steel content,
- thermal coefficient of expansion (CoTE) of the coarse aggregate and the concrete, and
- friction variables listed under the LTE cluster.

The steel cover is taken as 1 inch above the neutral axis of the slab (= h/2 – 1) and ranges ± 1 inch from that position.

The cracking cluster ranges from 0.5 to 3.0 where the crack spacing ranges from 30 to 90 inches and the RRS ranges from 30 to 60 inches. Figure 4-1 illustrates the effect of the cracking cluster on punchout performance per mile (po/mi) for the Dry-Cold case. The default punchout rate for the Dry-Cold case is 16.4 po/mi. The factor levels are listed in Table 4-1 below, and the predicted punchout rate is plotted in Figure 4-1 relative to each high and low level of each factor. The factors included in Table 4-1 are key to either the radius of relative stiffness or to fatigue cracking. The concrete modulus of elasticity (E), slab thickness (h), and slab support (k) are included in the expression for rrs. The factors of steel content (%p), coefficient of friction (CoF), slab thickness (h), and steel cover increase the punchout rate as they change from their low to high level. These trends are expected because of the effect of them on the shear capacity of the transverse cracks. However, for the factors of CoTE, concrete modulus of elasticity (E PCC), and the zero-stress temperature (T set), the opposite is true. The trend for the elasticity modulus occurs because of the increased climatic curling stresses with the higher modulus value, which increases the fatigue damage computed by the software and, hence, a higher punchout rate. All of the other trends are expected due to the effect on wider crack widths and reduced shear capacity of the transverse cracks.

Table 4-1. Cracking Cluster Factors.

	Factors	Low	High
RRS Related	E (psi)	5×10^6	3.2×10^6
	h (in.)	15.0	11.0
	k (psi/in.)	100	250
Cracking Related	Steel Cover	3.25"	1" above neutral axis
	Zero Stress Temp	+ 23 °F	-27 °F
	Percent Steel	-0.2%	0.002
	CoTE	+3	-2
	f	+2.9	-3.2

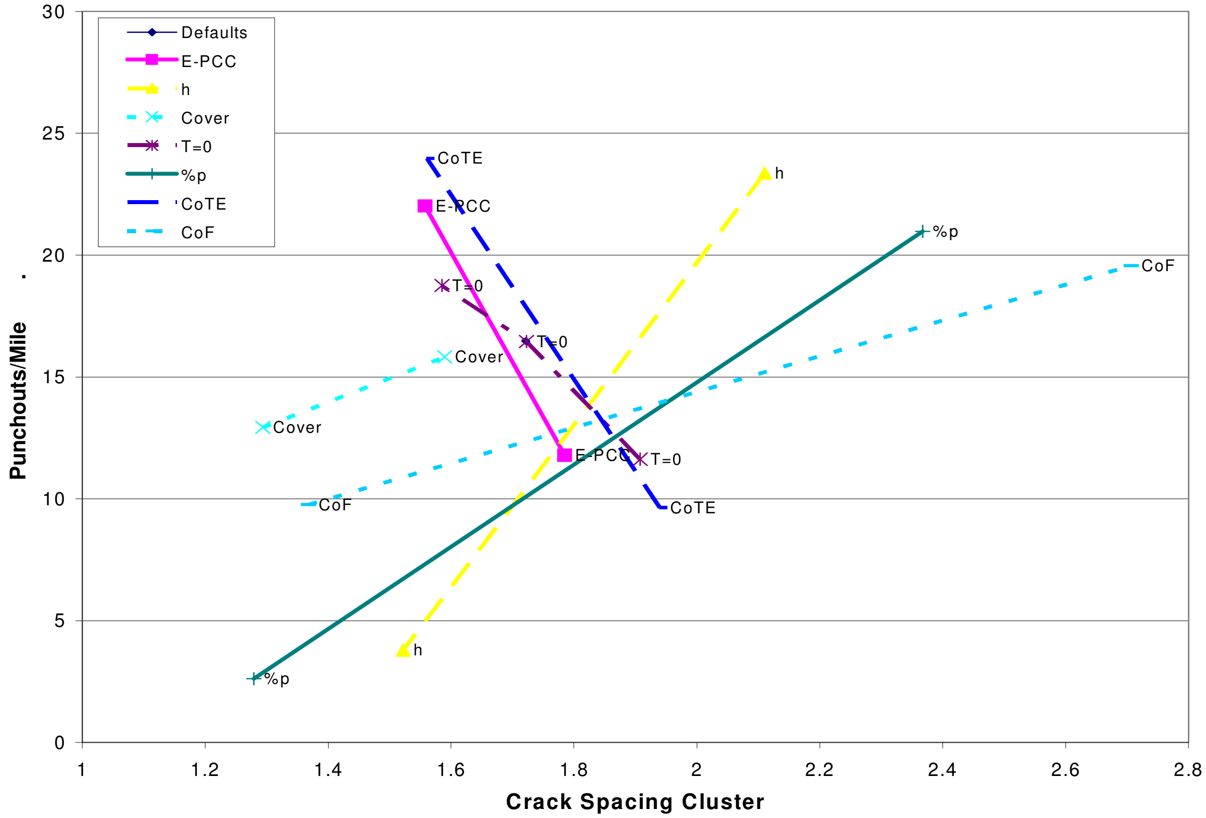


Figure 4-1. Variation of the Individual Factors Included in the Cracking Cluster for the Dry-Cold Case.

4.1.2 Load Transfer Efficiency (LTE) Cluster

The LTE cluster is related directly to the crack width of the transverse cracks as:

$$LTE\ Cluster = \frac{cw_{avg}}{h}; = \frac{\sum cw_i \left(T_{i+1} - T_i\right)}{30\ yrs}$$

where the cw_{avg} is the average crack width over the time interval T_{i+1} – T, and h is the slab thickness. The value of this cluster ranges from 1.0 to 4.0. Several factors can be listed that affect crack width such as:

- crack spacing,
- CoTE,
- slab friction,
- bar size,
- percent steel,
- zero-stress temperature,
- ultimate shrinkage strain, and
- temperature change.

Figure 4-2 illustrates the effect of each factor on performance relative to the punchout rate for the Dry-Cold case at the high and low levels indicated in Table 4-2. Table 4-2 includes factors which affect LTE and, as would be expected, are key players in the design crack width since the width of the crack is the main factor in load transfer. Typically speaking, as the steel cover, zero-stress temperature, curling temperature difference, and concrete CoTE decrease and as the percent steel and friction factor increase, the width of the crack decreases. The other factors of concrete modulus and slab thickness are included because they have an effect on LTE through the crack stiffness. Larger thicknesses and modulus increase crack stiffness and, ultimately, LTE. These levels are identical to the levels previously described in Table 4-1. The trends indicate the direct role that crack width has on performance in terms of the effect on shear capacity of the transverse cracks. The better the shear capacity, the more stiff will be the transverse crack and the lower the rate of damage and punchout. The only exception is the modulus of elasticity effect, which is due to increased concrete strength; the higher modulus correlates to the higher concrete strength, yielding a smaller punchout rate. The effect of the CoTE and T set are also opposite of those shown in Figure 4-1.

The M-E Design Guide performance model is not sensitive to the temperature difference between the top and the bottom of the pavement.

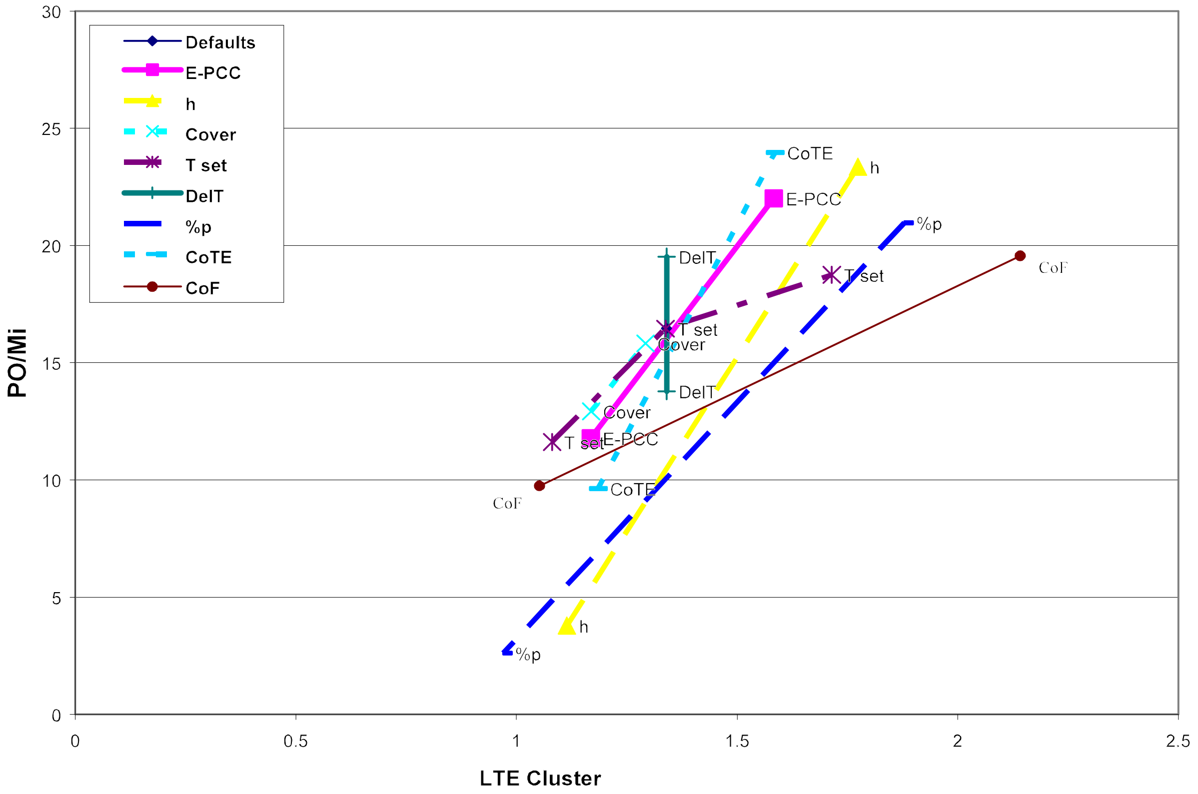


Figure 4-2. Variation of the Individual Factors Included in the LTE Cluster for the Dry-Cold Case.

Table 4-2. LTE Cluster Factor Levels.

	Factors	Low	High
Crack Width Related	Steel Cover	3.25"	1" above N.A.
	Zero-Stress Temp	+ 23 °F	-27 °F
	Curl Temp Diff	-5	+4
	% Steel	+0.2	-0.2
	CoTE	+3	-2
	f	+2.9	- 3.2
Others	E (psi)	5×10^6	3.2×10^6
	h (in.)	15.0	11.0

4.1.3 Traffic Cluster

This cluster is defined as the level of average annual daily truck traffic. In this project, the AADT level ranged from −1600 to +1600 (± 20 percent) above the base AADT. The punchout rate per mile was 13.5 and 18.4, respectively, for the Dry-Cold case. The trend in performance is obvious where greater AADT levels result in greater fatigue damage and greater punchout distress.

4.1.4 Damage Cluster

The damage cluster takes into account the different stresses that contribute to the fatigue in the pavement system. The general expression for fatigue damage accumulations is:

$$FD = \sum \frac{n_{i,\,j,\,k,\,l,\,m,\,n}}{N_{i,\,j,\,k,\,l,\,m,\,n}}$$

where

FD = Total fatigue damage (top-down or bottom-up)

$n_{i,j,k,l,m,n}$ = Number of applied axle load applications for the conditions noted below

$N_{i,j,k,l,m,n}$ = Number of allowable axle load applications for the conditions noted below to crack initiation in PCC

i = Age (accounts for change in PCC modulus of rupture, layer bond condition, and deterioration of shoulder LTE)

j = Month (accounts for change in base and effective modulus of subgrade reaction)

k = Axle type (single, tandem, and tridem)

l = Load level (incremental load for each axle type)

m = Temperature difference

n = Traffic path

The applied number of load applications ($n_{i,j,k,l,m,n}$) is the actual number of axle type k of load level l that passed through traffic path n under each condition (age, season, and temperature difference). The allowable number of load applications is the number of load cycles at which fatigue failure is expected and is a function of the applied stress and PCC strength. The allowable number of load applications is determined using the following fatigue model:

$$\log\left(N_{i,j,k,l,m,n}\right) = C_1\left(\frac{MR_i}{\sigma_{i,j,k,l,m,n}}\right)^{C_2} - 1$$

where

$N_{i,j,k,\ldots}$ = Allowable number of load applications at condition i, j, k, l, m, n

MR_i = PCC modulus of rupture at age i, psi

$\sigma_{i,j,k,\ldots}$ = Applied stress at condition i, j, k, l, m, n

C_1 = Calibration constant = 2.0

C_2 = Calibration constant = 1.22

The damage cluster is defined as:

$$\text{Damage Cluster} = \sum \frac{\text{n}}{\text{N}}$$

and ranges from 0.4 to 0.7. Note that the load induced stress is a function of the load location (D) from the longitudinal construction joint. The modulus of rupture is averaged over the analysis period as:

$$MR = \frac{\Sigma\, MR_i\left(T_{i+1} - T_i\right)}{30\ yrs}$$

The punchouts associated with these cluster values are listed in parentheses in Table 4-3. The punchout rate increases as either the stress related factors increase or the strength related factors decrease.

Table 4-3. Damage Cluster Factor (Dry-Cold Case).

	Factors	Low	High
Stress Related	Load location	4" farther (9.0)	4" closer (20.7)
Strength Related	MR	+50 psi (13.3)	−40 psi (18.7)

4.2 FOCUSED SENSITIVITY STUDIES IN HMAC PAVEMENTS

The following areas of interest were investigated to determine the impacts of these specific areas on the performance of HMAC pavements.

4.2.1 Environmental Effects

Environmental conditions have a very pronounced effect on the performance of pavements because they affect the mechanical properties of the materials and, by themselves, cause stressing, straining, and deformations that lead to specific types of failure, such as thermal cracking in flexible pavements, in addition to contributing to the other types of distresses. Engineers have always indirectly taken environmental conditions into account by incorporating specific ways for testing the materials (for example, the suction sequence in the Texas Triaxial Test, the soaking in the CBR), and in the empirical design procedures by local calibration (such as the district temperature constant in FPS19W). The M-E Design Guide is the first pavement analysis program that directly includes the environmental effects in a basic and mechanistic manner. The program is specific to the U.S. because it uses weather stations from North America only; it is, however, formulated in such a general way to be able to include all climatic conditions.

Because the environmental effects are very important, the predictions of temperature (in the surface layers and for frost and thaw depth computations in the lower layers) and moisture content (in the unbound materials) should be very carefully checked and compared with actual values measured in test sections. The temperature and moisture distributions are obtained from the EICM for each hour during the design period and at different depths in the structure. They are used for modifying the material properties (moduli) in the surface and unbound materials and for computing the amount of thermal cracking in HMAC pavements.

The actual “environmental” conditions in a pavement structure involve very complex processes, which may be coupled. This coupling can greatly complicate the computation process. To be practical, the EICM ignores the coupling in most cases and uses simple types of analyses, i.e., one-dimensional (1-D) as opposed to two-dimensional (2-D) conditions. Fortunately, the conditions in the interior part of the pavement structure, far from the ditches, should correspond to the 1-D predictions.

The number of variables involved in calculating the environmental effects is very large. Most of them affect the prediction of the temperature and moisture distribution. A list of these variables is given below:

- ICM stations: are identified by their latitude, longitude, and elevation. Each station contains hourly information on:
  - air temperature,
  - precipitation,
  - wind speed,
  - percentage sunshine, and
  - relative humidity.

- Depth to groundwater table

- Drainage and surface properties:
    - infiltration,
    - drainage length, and
    - pavement cross slope.

- Pavement structure:
    - layer type,
    - layer thickness, and
    - layers subdivided.

- Material inputs:
    - All materials: thermal conductivity and heat and thermal capacity (in a dry condition for the unbound)
    - Asphalt materials properties: surface shortwave absorptivity; and
    - Compacted unbound materials properties: maximum dry unit weight, specific gravity of solids, optimum gravimetric water content, saturated hydraulic conductivity, and Soil Water Suction Curve (SWSC) or the parameters of the curve. These variables may be evaluated from the gradation (P200, P4, and D60) and the plasticity index (PI). For rehabilitation, the gravimetric water content at equilibrium is required.

The above parameters are used to solve the problems of heat and water flow and to obtain the temperature and water content distributions during the design period. The following sensitivity analyses are aimed to complement the general sensitivity study described in Section 2.1 and illustrate the effect of some variables on the various moduli.

4.2.1.1 Effect of Choice of Weather Station

Different weather stations record different values for the data they collect, so it is expected that the predicted moduli will be somewhat different if another weather station is used. However, if the stations are located closely enough to each other, the difference should be minor. Also, the effect of averaging multiple stations in the same region (similar elevation and conditions within 50 miles) on performance measures should not exceed a few percent. In the following example runs of the program, the moduli of the AC, granular base, and subgrade, as well as the predicted performance are compared. The pavement structure corresponds to the LTPP GPS section 480001, and the traffic is composed of only 36 kip tandem axles. In order to predict reasonable results, the calibration factors developed in Section 2.2.1 were used.

a. Two different weather stations were chosen: Burnet, TX (station 03999, latitude = 30.11, longitude = 98.14) and Austin/Bergstrom, TX (station 13904, latitude = 30.11, longitude = 97.41). The water table was kept at 17 ft deep. Figures 4-3 and 4-4 present the variation of the moduli of the subgrade, in different sublayers, for runs from the two stations. In this case, the subgrade moduli are the same. Figures 4-5 and 4-6 present the variation of the moduli in the base, in the different sublayers, for the two stations. Here, the results are somewhat different. Figure 4-7 presents a comparison between the stations. Note that only the upper sublayer has a different modulus. This may be due to the fact that the Burnet station is slightly north and at a slightly higher elevation compared to the Bergstrom station. Therefore, with the Burnet climate, during a few hours per year, frost will penetrate to the upper base layer. During the period of recovery, the modulus of the upper base sublayer is lower. For the month, on the average, the modulus drops from 32,000 psi to 24,000 psi (see Figure 4-5).

These runs of the program illustrate the complexity of the processes involved in the environmental effects.

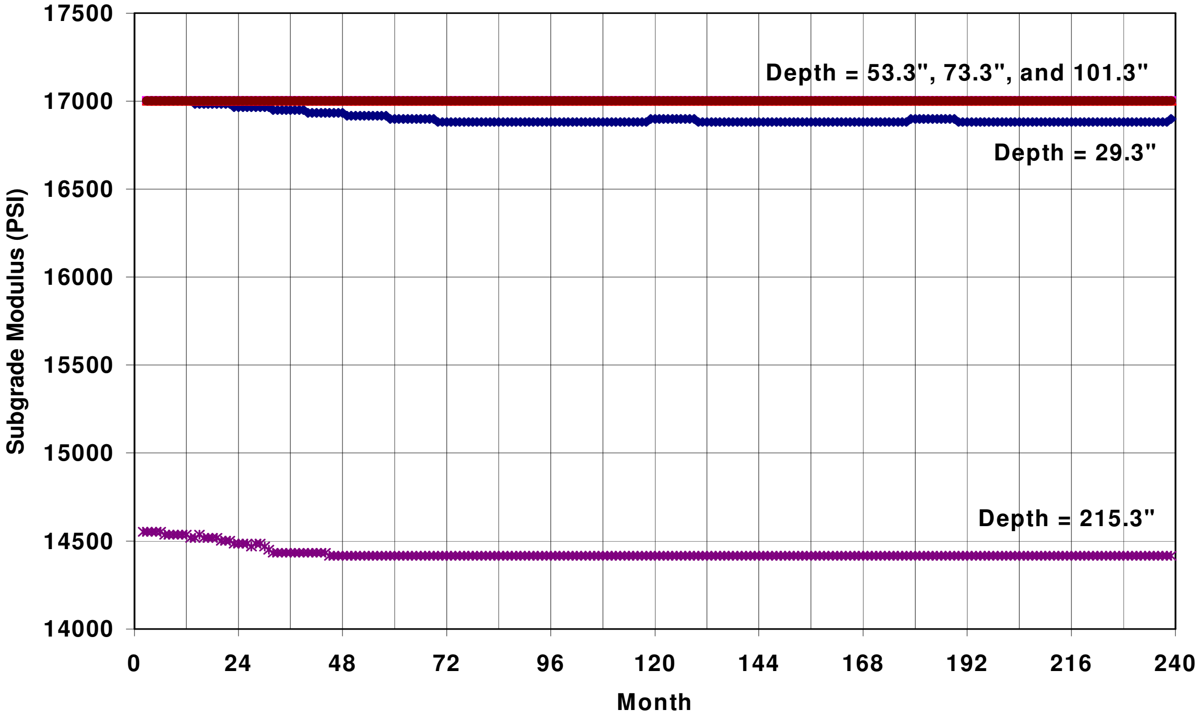


Figure 4-3. Subgrade Modulus Results for 480001 Using Burnet Weather Station Only.

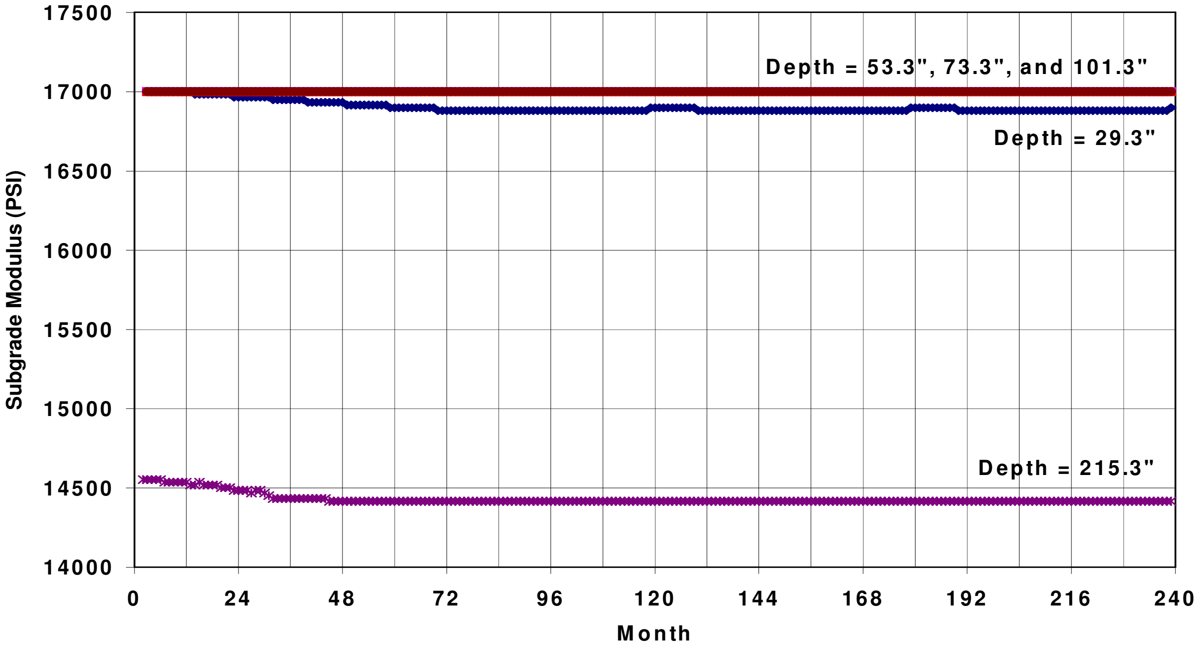


Figure 4-4. Subgrade Modulus Results for 480001 Using Bergstrom Weather Station Only.

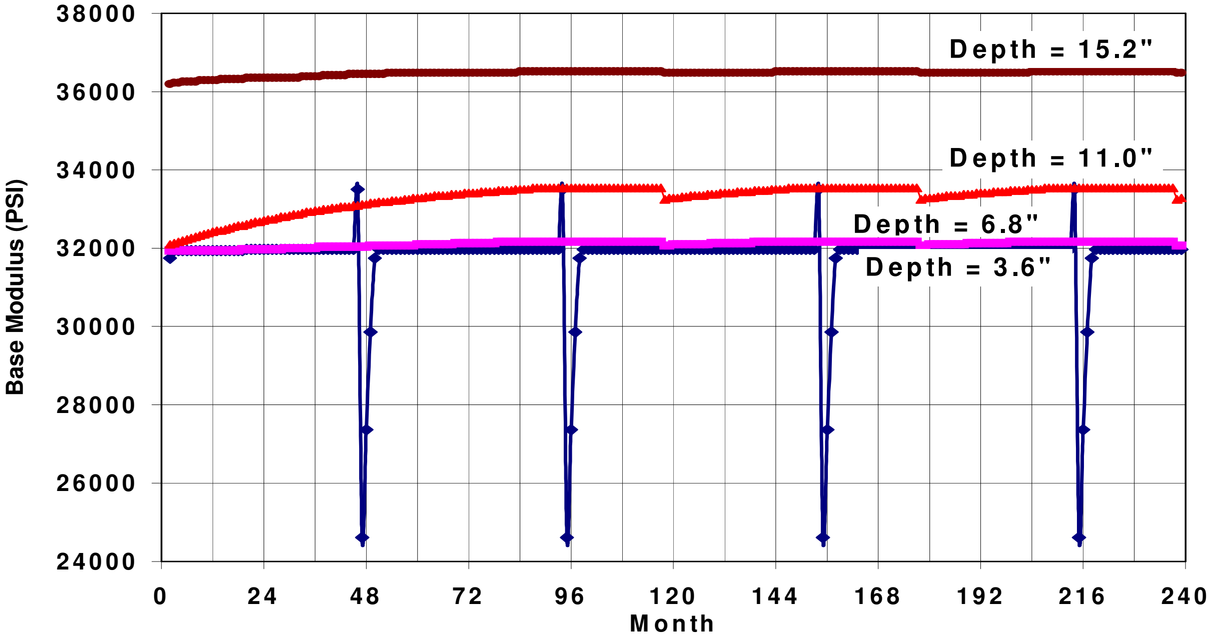


Figure 4-5. Base Layer Modulus Results for 480001 Using Burnet Weather Station Only.

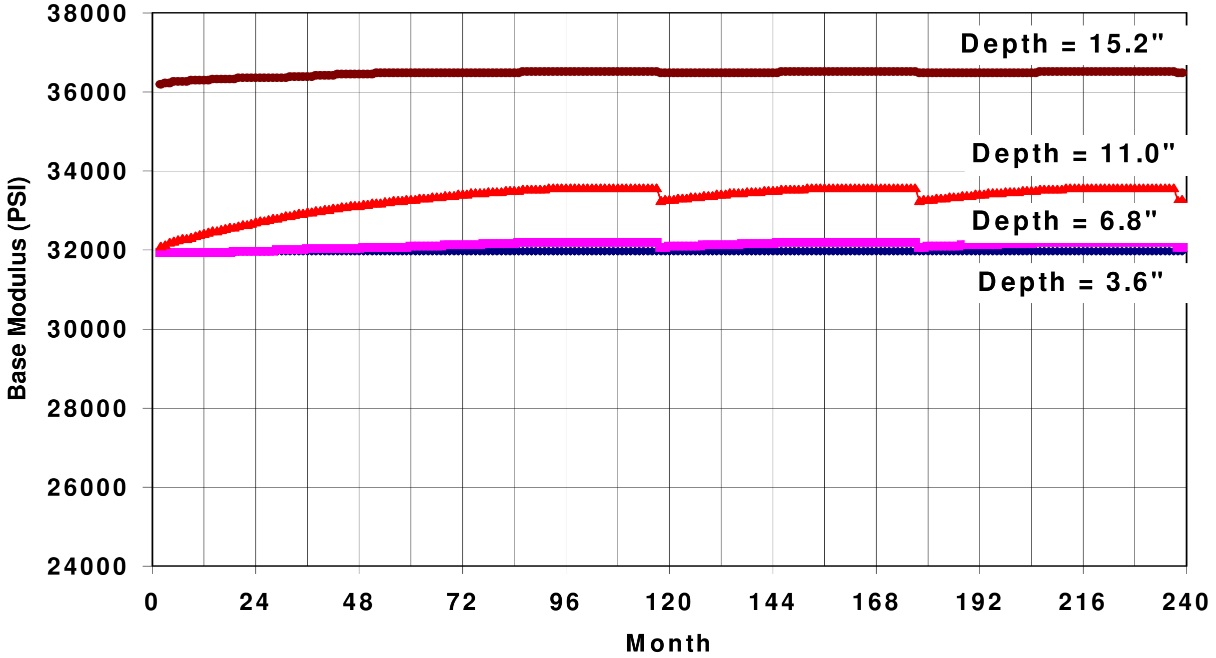


Figure 4-6. Base Layer Modulus Results for 480001 Using Bergstrom Weather Station Only.

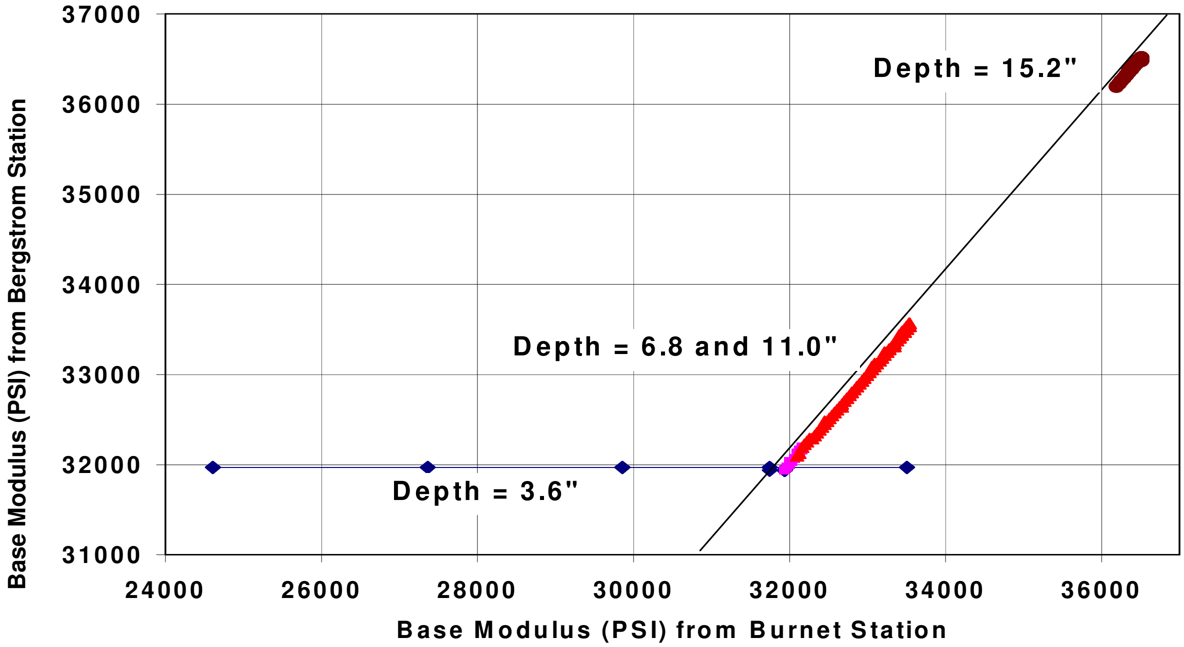


Figure 4-7. Comparison of Base Modulus Results for 480001 over Time Using Burnet and Bergstrom Weather Stations.

Figures 4-8 and 4-9 present the evolution of damage-cracking, rutting, and IRI for the two weather stations at site 480001. There seems to be an effect on the performance prediction; the cracking and the rut depth are higher for the Burnet weather station than for climatic conditions at the Bergstrom site. IRI and fatigue cracking are similar for both weather stations.

b. Three weather stations – Burnet, Bergstrom, and Austin/city (station 13958, latitude = 30.19, longitude = 97.46) – were chosen for the generation of the virtual weather station specific to the pavement test site location. Figures 4-10 and 4-11 present results of analyses in terms of modulus of the base and damage evolution, respectively, for the virtual station. These are similar to the results obtained for the Burnet station alone, suggesting that the frost and thaw action from the Burnet station was kept in the virtual station.

4.2.1.2 Effect of Depth of Water Table (WT)

The depth to the water table controls the moisture content regime (and the modulus) of the layer above it. The distance or radius of influence depends on the material type. For a clayey material, the water table effect can extend to 10 to 20 ft (3 to 6 m). Usually when the water table depth is greater than about 20 ft (6 m), it has little or no effect on the modulus of the upper subgrade layer supporting the pavement. The reason for this is the flow rate in unsaturated soils, which can be very low. The infiltration from the surface and the granular base or subbase materials controls the moisture regime of the upper subgrade. The following runs illustrate the effect of the water table depth on the modulus and performance of the trial section.

In these runs, the water table depth for GPS section 480001 was changed from 17 to 40 feet and 5 to 17 feet. Figures 4-12 through 4-15 illustrate the effect on the base and subgrade moduli in the different sublayers. It is clear that no effect is noted when the water table depth is increased from 17 to 40 ft (except for the lower subgrade layer). When the water table depth is closer to the surface (from 17 to 5 ft) the result is an appreciable reduction of the moduli of the base and subgrade. This may affect the pavement performance in the same way as specifying a softer base or subgrade. Figures 4-11, 4-16, and 4-17 illustrate this effect, which seems to be minor, for the pavement structure being analyzed.

Pavement age		Month	Logitudinal Cracking (ft/mi)	Alligator Cracking (%)	Transverse Cracking (ft/mi)	Subtotal AC Rutting (in)	Total Rutting (in)	IRI (in/mi)	Heavy Trucks (cumulative)	IRI at Reliability (in/mi)
mo	yr									
1	0.08	April	0.01	0.0191	0	0.023	0.131	161.9	7229	193.45
13	1.08	April	0.98	0.7	0	0.135	0.297	165	93976	196.6
25	2.08	April	2.56	1.82	0	0.187	0.362	168.2	180723	199.82
37	3.08	April	4.29	3.18	0	0.222	0.405	171.5	267470	203.06
49	4.08	April	6.16	4.66	0	0.25	0.439	174.7	354216	206.29
61	5.08	April	8.14	6.25	0	0.274	0.469	178	440963	209.57
73	6.08	April	10.4	8.01	0	0.298	0.496	181.4	527710	212.99
85	7.08	April	12.7	9.84	0	0.318	0.52	184.9	614457	216.49
97	8.08	April	15	11.6	0	0.336	0.541	188.4	701204	219.98
109	9.08	April	17.4	13.5	0	0.353	0.56	191.9	787951	223.55
121	10.1	April	20.2	15.3	0	0.37	0.58	195.6	874698	227.26
133	11.1	April	23	17.3	0	0.387	0.598	199.4	961445	231.09
145	12.1	April	25.8	19.2	0	0.402	0.615	203.3	1048190	235.01
157	13.1	April	28.6	21	0	0.415	0.63	207.2	1134940	238.9
169	14.1	April	31.5	22.8	0	0.429	0.645	211.4	1221690	243.07
181	15.1	April	34.7	24.6	0	0.442	0.66	215.6	1308430	247.36
193	16.1	April	38	26.4	0	0.456	0.675	219.8	1395180	251.53
205	17.1	April	41.1	28.2	0	0.468	0.688	224.3	1481930	256.06
217	18.1	April	44.4	29.9	0	0.479	0.701	228.9	1568670	260.74
229	19.1	April	47.7	31.6	0	0.49	0.713	233.5	1655420	265.31
240	20	March	51	33	0	0.502	0.725	237.9	1734940	269.78

Figure 4-8. Performance Prediction for 480001 Using Burnet Weather Station Only.

Pavement age		Month	Logitudinal Cracking (ft/mi)	Alligator Cracking (%)	Transverse Cracking (ft/mi)	Subtotal AC Rutting (in)	Total Rutting (in)	IRI (in/mi)	Heavy Trucks (cumulative)	IRI at Reliability (in/mi)
mo	yr									
1	0.08	April	0.01	0.0178	0	0.027	0.135	161.8	7229	193.44
13	1.08	April	0.9	0.736	0	0.125	0.286	165.1	93976	196.66
25	2.08	April	1.96	1.85	0	0.161	0.335	168.2	180723	199.82
37	3.08	April	3.1	3.12	0	0.187	0.369	171.3	267470	202.91
49	4.08	April	4.62	4.63	0	0.216	0.403	174.5	354216	206.15
61	5.08	April	5.99	6.25	0	0.235	0.427	177.8	440963	209.45
73	6.08	April	7.41	7.89	0	0.252	0.447	181.1	527710	212.7
85	7.08	April	9.19	9.69	0	0.271	0.471	184.5	614457	216.15
97	8.08	April	10.8	11.5	0	0.286	0.488	188	701204	219.63
109	9.08	April	12.4	13.3	0	0.299	0.503	191.5	787951	223.12
121	10.1	April	14.4	15.2	0	0.315	0.522	195.2	874698	226.79
133	11.1	April	16.2	16.9	0	0.327	0.535	198.8	961445	230.47
145	12.1	April	18.4	18.8	0	0.342	0.552	202.6	1048190	234.31
157	13.1	April	20.3	20.7	0	0.353	0.565	206.6	1134940	238.28
169	14.1	April	22.2	22.4	0	0.363	0.576	210.5	1221690	242.16
181	15.1	April	24.6	24.3	0	0.376	0.591	214.7	1308430	246.4
193	16.1	April	26.6	25.9	0	0.386	0.602	218.8	1395180	250.52
205	17.1	April	29.1	27.7	0	0.398	0.615	223.2	1481930	255.01
217	18.1	April	31.3	29.4	0	0.407	0.625	227.8	1568670	259.63
229	19.1	April	33.5	31	0	0.416	0.635	232.3	1655420	264.15
240	20	March	36	32.5	0	0.426	0.647	236.7	1734940	268.57

Figure 4-9. Performance Prediction for 480001 Using Bergstrom Weather Station Only.

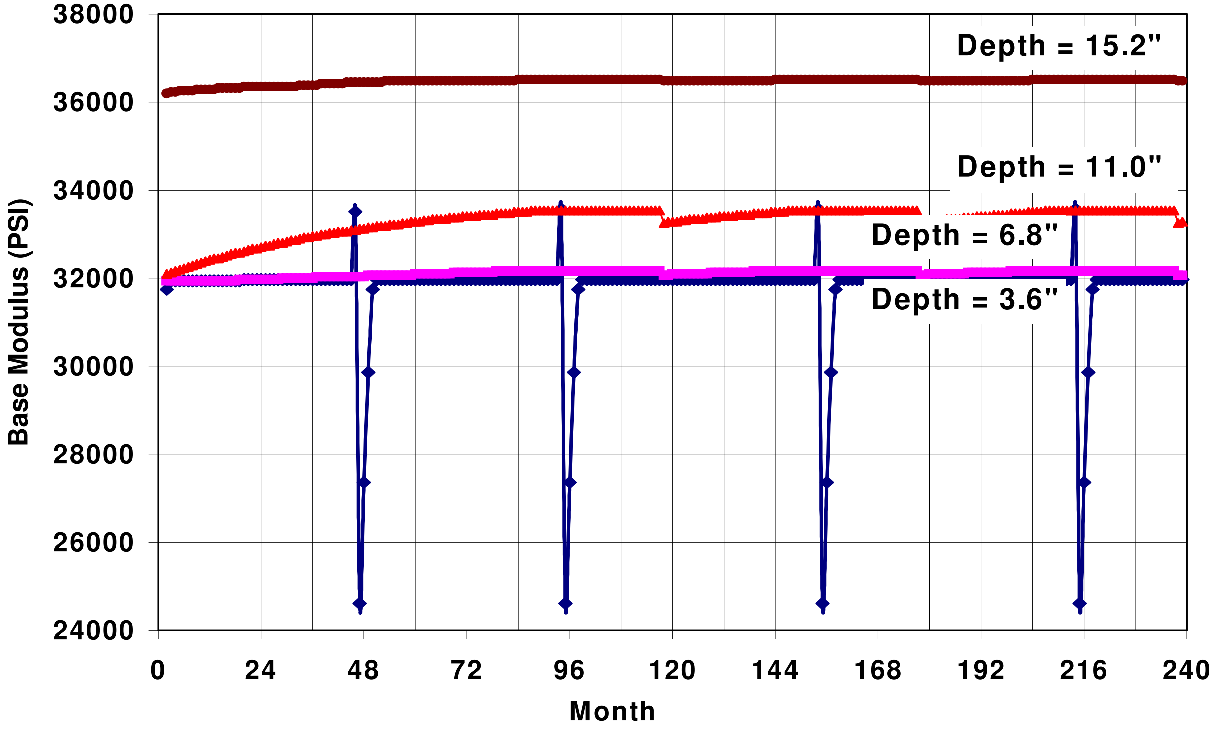


Figure 4-10. Base Modulus Variation for 480001 Using Three Weather Stations.

Pavement age		Month	Logitudinal Cracking (ft/mi)	Alligator Cracking (%)	Transverse Cracking (ft/mi)	Subtotal AC Rutting (in)	Total Rutting (in)	IRI (in/mi)	Heavy Trucks (cumulative)	IRI at Reliability (in/mi)
mo	yr									
1	0.08	April	0.01	0.0191	0	0.023	0.131	161.9	7229	193.45
13	1.08	April	0.98	0.699	0	0.135	0.296	165	93976	196.59
25	2.08	April	2.5	1.82	0	0.184	0.36	168.2	180723	199.79
37	3.08	April	4.13	3.18	0	0.217	0.401	171.4	267470	203.02
49	4.08	April	5.89	4.65	0	0.244	0.433	174.6	354216	206.21
61	5.08	April	7.84	6.24	0	0.269	0.463	177.9	440963	209.47
73	6.08	April	10	7.99	0	0.292	0.49	181.3	527710	212.88
85	7.08	April	12.1	9.81	0	0.311	0.512	184.7	614457	216.34
97	8.08	April	14.3	11.6	0	0.328	0.532	188.2	701204	219.84
109	9.08	April	16.7	13.4	0	0.346	0.552	191.8	787951	223.39
121	10.1	April	19.3	15.3	0	0.362	0.571	195.4	874698	227.06
133	11.1	April	22	17.2	0	0.378	0.589	199.2	961445	230.87
145	12.1	April	24.6	19.1	0	0.392	0.605	203.1	1048190	234.77
157	13.1	April	27.3	20.9	0	0.405	0.62	207	1134940	238.69
169	14.1	April	30.1	22.7	0	0.419	0.635	211.1	1221690	242.84
181	15.1	April	33.1	24.6	0	0.432	0.649	215.1	1308430	246.85
193	16.1	April	36.3	26.3	0	0.445	0.664	219.5	1395180	251.24
205	17.1	April	39.3	28.1	0	0.457	0.677	224	1481930	255.75
217	18.1	April	42.3	29.8	0	0.468	0.689	228.6	1568670	260.39
229	19.1	April	45.5	31.5	0	0.479	0.701	233.1	1655420	264.94
240	20	March	48.8	33	0	0.49	0.713	237.5	1734940	269.38

Figure 4-11. Performance Prediction for 480001 Using Three Weather Stations.

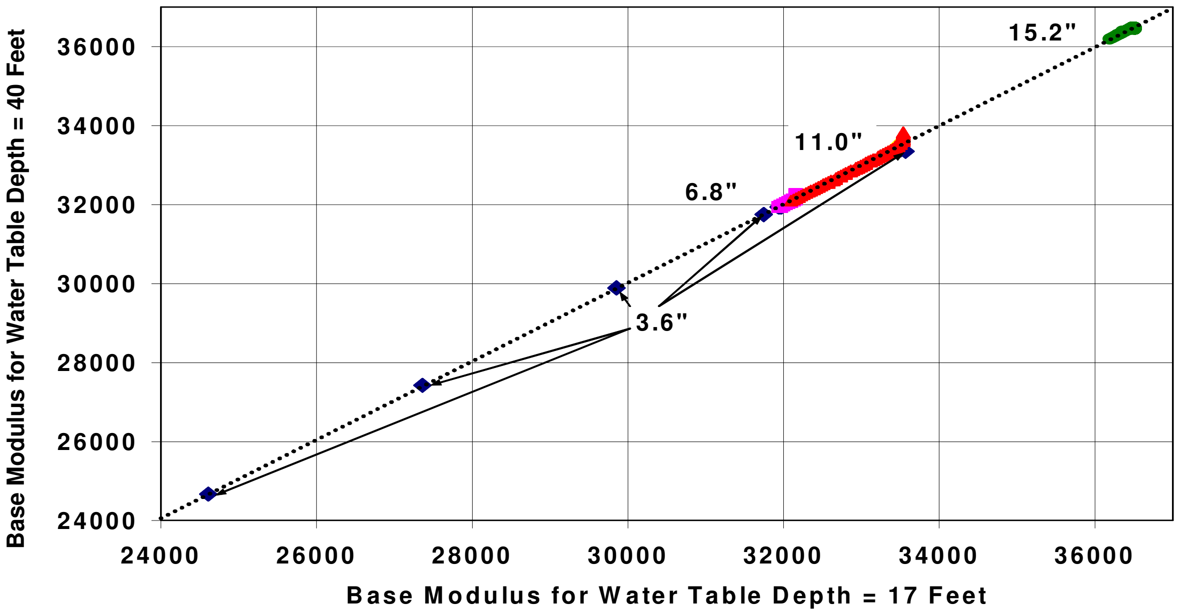


Figure 4-12. Comparison of Base Modulus for 480001 with Water Table Depth of 17 and 40 Feet.

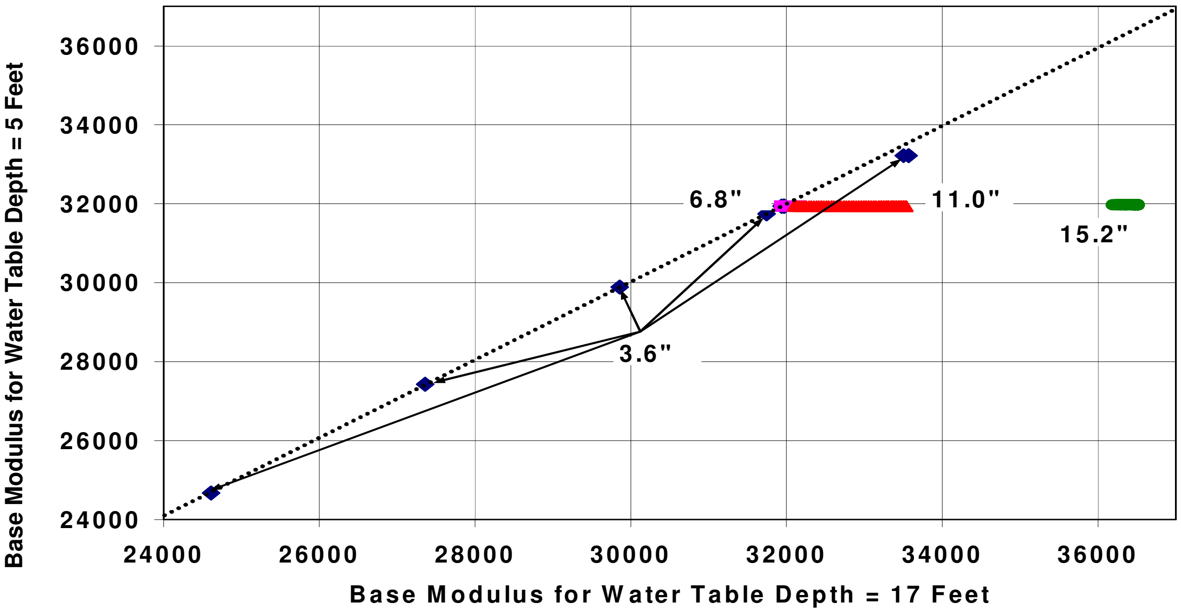


Figure 4-13. Comparison of Base Modulus for 480001 with Water Table Depth of 5 and 17 Feet.

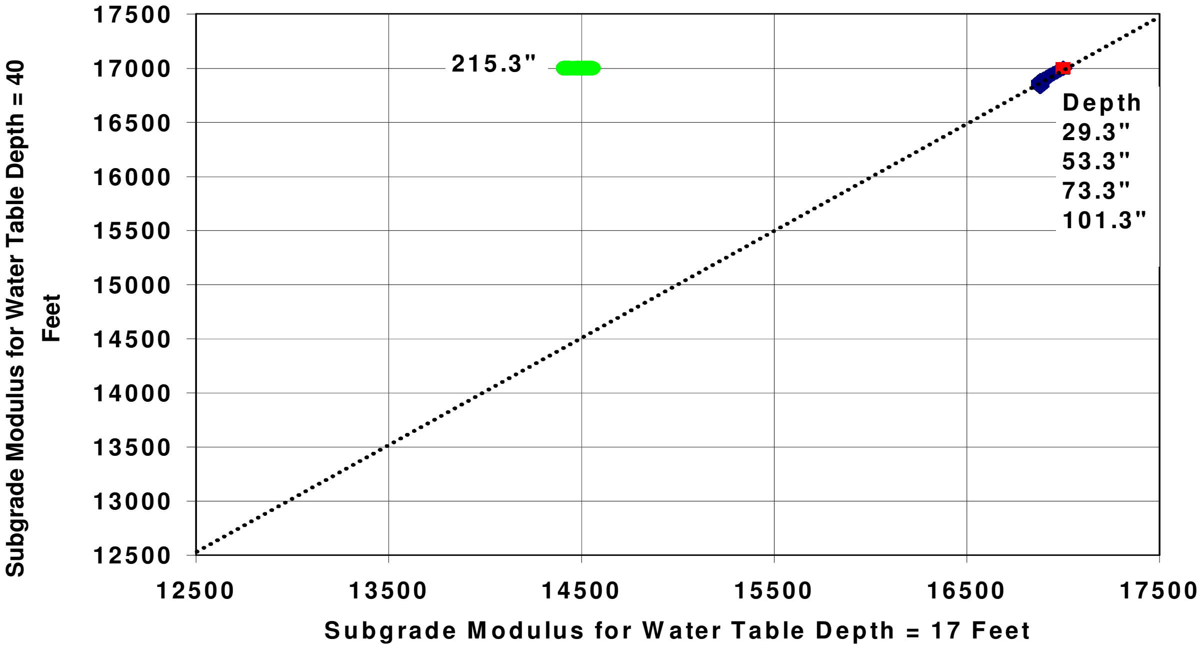


Figure 4-14. Comparison of Subgrade Modulus at 480001 for Water Table Depth of 17 and 40 Feet.

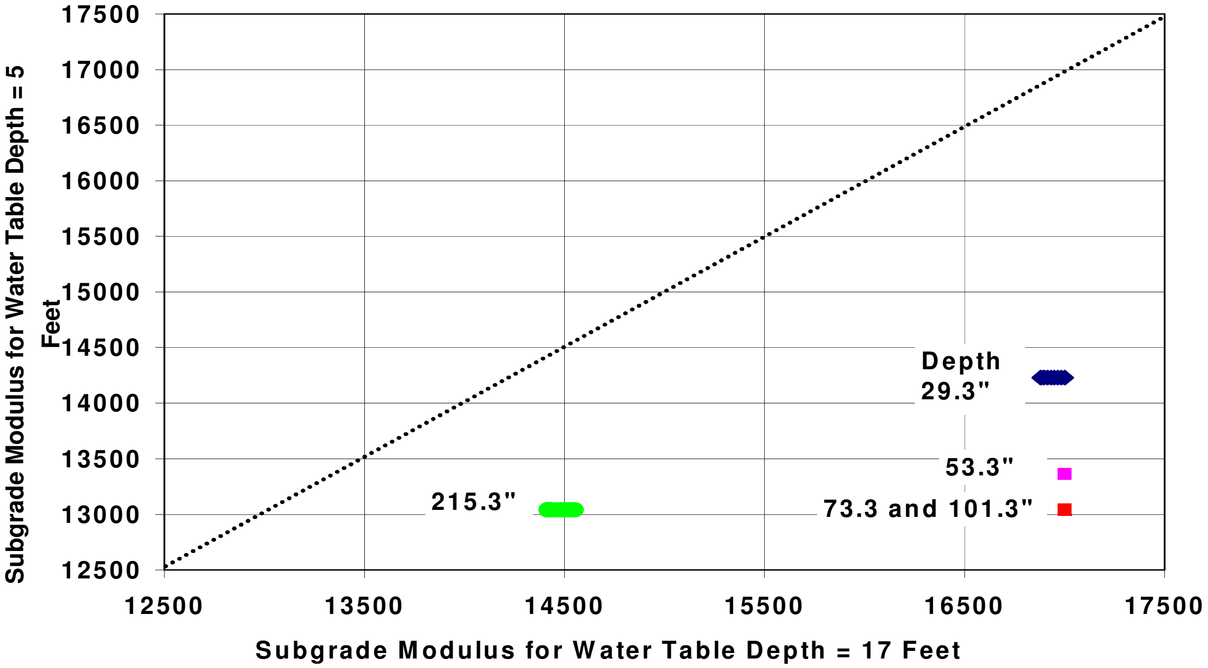


Figure 4-15. Comparison of Subgrade Modulus at 480001 for Water Table Depth of 5 and 17 Feet.

Pavement age		Month	Logitudinal Cracking (ft/mi)	Alligator Cracking (%)	Transverse Cracking (ft/mi)	Subtotal AC Rutting (in)	Total Rutting (in)	IRI (in/mi)	Heavy Trucks (cumulative)	IRI at Reliability (in/mi)
mo	yr									
1	0.08	April	0.01	0.0191	0	0.023	0.131	161.9	7229	193.45
13	1.08	April	0.99	0.701	0	0.134	0.296	165	93976	196.59
25	2.08	April	2.52	1.82	0	0.184	0.359	168.2	180723	199.79
37	3.08	April	4.17	3.19	0	0.216	0.4	171.4	267470	203.02
49	4.08	April	5.94	4.66	0	0.243	0.432	174.6	354216	206.24
61	5.08	April	7.91	6.26	0	0.268	0.461	177.9	440963	209.5
73	6.08	April	10.1	8.02	0	0.291	0.488	181.3	527710	212.91
85	7.08	April	12.2	9.85	0	0.309	0.51	184.8	614457	216.39
97	8.08	April	14.5	11.7	0	0.327	0.53	188.3	701204	219.88
109	9.08	April	16.9	13.5	0	0.344	0.55	191.8	787951	223.44
121	10.1	April	19.5	15.4	0	0.361	0.569	195.5	874698	227.13
133	11.1	April	22.2	17.3	0	0.377	0.587	199.3	961445	230.94
145	12.1	April	24.8	19.2	0	0.391	0.603	203.2	1048190	234.85
157	13.1	April	27.5	21	0	0.404	0.617	207	1134940	238.69
169	14.1	April	30.4	22.8	0	0.417	0.632	211.1	1221690	242.84
181	15.1	April	33.5	24.6	0	0.431	0.647	215.4	1308430	247.1
193	16.1	April	36.6	26.4	0	0.443	0.661	219.5	1395180	251.24
205	17.1	April	39.6	28.3	0	0.455	0.674	224	1481930	255.75
217	18.1	April	42.7	29.9	0	0.466	0.686	228.6	1568670	260.39
229	19.1	April	45.9	31.6	0	0.477	0.699	233.1	1655420	264.94
240	20	March	49.2	33.1	0	0.488	0.711	237.7	1734940	269.62

Figure 4-16. Performance Prediction at 480001 for Water Table at 40 Feet.

Pavement age		Month	Logitudinal Cracking (ft/mi)	Alligator Cracking (%)	Transverse Cracking (ft/mi)	Subtotal AC Rutting (in)	Total Rutting (in)	IRI (in/mi)	Heavy Trucks (cumulative)	IRI at Reliability (in/mi)
mo	yr									
1	0.08	April	0.01	0.02	0	0.023	0.134	161.9	7229	193.46
13	1.08	April	0.78	0.723	0	0.134	0.301	165	93976	196.64
25	2.08	April	1.99	1.88	0	0.183	0.365	168.3	180723	199.89
37	3.08	April	3.3	3.28	0	0.215	0.406	171.6	267470	203.16
49	4.08	April	4.72	4.81	0	0.242	0.439	174.8	354216	206.4
61	5.08	April	6.31	6.43	0	0.267	0.468	178.1	440963	209.69
73	6.08	April	8.08	8.22	0	0.289	0.495	181.5	527710	213.13
85	7.08	April	9.82	10.1	0	0.308	0.517	185	614457	216.63
97	8.08	April	11.6	11.9	0	0.326	0.537	188.5	701204	220.13
109	9.08	April	13.6	13.8	0	0.343	0.557	192.1	787951	223.7
121	10.1	April	15.7	15.7	0	0.36	0.576	195.8	874698	227.42
133	11.1	April	18	17.6	0	0.376	0.594	199.6	961445	231.25
145	12.1	April	20.1	19.5	0	0.389	0.61	203.5	1048190	235.19
157	13.1	April	22.3	21.4	0	0.402	0.625	207.5	1134940	239.17
169	14.1	April	24.7	23.2	0	0.416	0.64	211.6	1221690	243.32
181	15.1	April	27.2	25	0	0.429	0.655	215.6	1308430	247.34
193	16.1	April	29.7	26.9	0	0.442	0.669	220	1395180	251.72
205	17.1	April	32.2	28.6	0	0.454	0.682	224.5	1481930	256.23
217	18.1	April	34.7	30.3	0	0.464	0.694	229.1	1568670	260.88
229	19.1	April	37.4	32	0	0.476	0.706	233.8	1655420	265.67
240	20	March	40.1	33.5	0	0.487	0.718	238.2	1734940	270.11

Figure 4-17. Performance Prediction at 480001 for Water Table at 5 Feet.

4.2.2 Thermal Cracking

Thermal cracking is due to the contraction of the AC layers as the temperature drops in colder regions and a hardening of the binder as it ages. It is not typically a serious problem in Texas. Analysis of sites in using the M-E Design Guide with weather stations in Texas did not predict any transverse cracking. The transverse cracking observed in the north part of the state appears to be a reflection cracking from shrinkage or other cracking in the base layer. This type of distress is not included in the M-E Design Guide. TxDOT should address the “thermal cracking” in the north of the state locally, through its research program.

In the thermal cracking model, three basic material parameters – D1, m, and St (the intercept and slope of the creep curve, and the tensile strength) – and the weather conditions (including the parameters for the heat flow – surface absorptivity, conductivity, and heat capacity) control the occurrence and density (or spacing) of the transversal cracking. The material parameters are required for data Levels 1 and 2 types of analysis; they are derived from volumetric properties of the mix (Vb_{eff} – the effective volume percentage of the binder, Va – the percent of air voids in the mix) and binder properties (Pen@77 – penetration at 77°F, A_{RTFO} – the intercept of the log-viscosity curve with respect to log-log-temperature, after RTFO aging) for Level 3 type of analysis.

As no transverse cracking could be induced when using Texas weather stations, the results of runs presented in this paragraph were made using a weather station located in Illinois (Champaign.ICM). Two different analyses were made: one for the basic material variables (Level 2) and the other for the mix and binder properties (Level 3). Table 4-4 summarizes the values of the parameters used to generate the data and run the program, and the results obtained. The parameters are defined as follows:

D_1 = Intercept of the creep curve at −10°C, in 1/psi
m = Slope of creep curve at −10°C
St = Tensile strength at −10°C, in psi
Va = Air voids (%)
Vb_{eff} = Effective asphalt content (%)
VFA = Voids filled with asphalt (%) = $100 \times Vb_{eff} / (Vb_{eff} + Va)$
VMA = Void in mineral aggregate (%) = $Vb_{eff} + Va$
A_{RTFO} = Intercept of binder viscosity-temperature relationship for the RTFO (Rolling Thin Film Oven) condition
Pen@77 = Penetration at 77°F
A = Intercept of binder viscosity-temperature relationship
VTS = Slope of binder viscosity-temperature relationship
Diff = $(A - A_{RTFO})$

The values in Table 4-4 cover a wide range for most parameters, especially for the asphalt grade.

Table 4-4. Variables Used in the Analysis.

												Trans. Cracking (ft/mi)	
D_1 (1/PSI)	m	St, psi	Va	Vb_{eff}	VFA	VMA	ARTFO	A	Diff	VTS	Pen@77	61 Mon	240 Mon
3.61E-07	0.222	398.47	4	9	69.2	13	10.534	10.534	0	-3.510	38.0	3.9	1160
3.31E-07	0.262	450.74	4	9	69.2	13	11.013	11.013	0	-3.695	64.0	0	3.4
3.04E-07	0.342	506.00	4	9	69.2	13	11.517	11.517	0	-3.890	109.6	0	0
3.95E-07	0.222	439.74	4	9	69.2	13	10.054	10.534	0.480	-3.510	38.0	2	770
3.61E-07	0.262	490.17	4	9	69.2	13	10.534	11.013	0.480	-3.695	64.0	0	1.9
3.30E-07	0.342	543.67	4	9	69.2	13	11.037	11.517	0.480	-3.890	109.6	0	0
4.36E-07	0.222	485.22	4	9	69.2	13	9.551	10.534	0.983	-3.510	38.0	1	409
3.97E-07	0.262	533.53	4	9	69.2	13	10.031	11.013	0.983	-3.695	64.0	0	1.0
3.61E-07	0.342	585.01	4	9	69.2	13	10.534	11.517	0.983	-3.890	109.6	0	0
4.24E-07	0.157	277.01	4	12	75.0	16	10.534	10.534	0	-3.510	38.0	1790	2110
3.89E-07	0.197	329.28	4	12	75.0	16	11.013	11.013	0	-3.695	64.0	659	1890
3.57E-07	0.277	384.53	4	12	75.0	16	11.517	11.517	0	-3.890	109.6	0	7.4
4.64E-07	0.157	318.28	4	12	75.0	16	10.054	10.534	0.480	-3.510	38.0	1700	2110
4.24E-07	0.197	368.71	4	12	75.0	16	10.534	11.013	0.480	-3.695	64.0	417	1860
3.88E-07	0.277	422.21	4	12	75.0	16	11.037	11.517	0.480	-3.890	109.6	0	3.8
5.12E-07	0.157	363.76	4	12	75.0	16	9.551	10.534	0.983	-3.510	38.0	1560	2110
4.66E-07	0.197	412.07	4	12	75.0	16	10.031	11.013	0.983	-3.695	64.0	218	1810
4.24E-07	0.277	463.54	4	12	75.0	16	10.534	11.517	0.983	-3.890	109.6	0	2
3.71E-07	0.230	491.03	7	9	56.3	16	10.534	10.534	0	-3.510	38.0	0.1	32.1
3.41E-07	0.270	534.30	7	9	56.3	16	11.013	11.013	0	-3.695	64.0	0	0.6
3.13E-07	0.351	598.55	7	9	56.3	16	11.517	11.517	0	-3.890	109.6	0	0
4.06E-07	0.230	532.30	7	9	56.3	16	10.054	10.534	0.480	-3.510	38.0	0.1	17
3.71E-07	0.270	582.73	7	9	56.3	16	10.534	11.013	0.480	-3.695	64.0	0	0.3
3.39E-07	0.351	636.23	7	9	56.3	16	11.037	11.517	0.480	-3.890	109.6	0	0
4.48E-07	0.230	577.78	7	9	56.3	16	9.551	10.534	0.983	-3.510	38.0	0	9
4.08E-07	0.270	626.09	7	9	56.3	16	10.031	11.013	0.983	-3.695	64.0	0	0.2
3.71E-07	0.351	677.56	7	9	56.3	16	10.534	11.517	0.983	-3.890	109.6	0	0
4.69E-07	0.152	224.87	7	12	63.2	19	10.534	10.534	0	-3.510	38.0	1900	2110
4.30E-07	0.192	277.14	7	12	63.2	19	11.013	11.013	0	-3.695	64.0	745	1960
3.50E-07	0.273	332.40	7	12	63.2	19	11.517	11.517	0	-3.890	109.6	0.1	11.1
5.12E-07	0.152	266.14	7	12	63.2	19	10.054	10.534	0.480	-3.510	38.0	1840	2110
4.69E-07	0.192	316.58	7	12	63.2	19	10.534	11.013	0.480	-3.695	64.0	651	1890
4.28E-07	0.273	370.07	7	12	63.2	19	11.037	11.517	0.480	-3.890	109.6	0	5.2
5.66E-07	0.152	311.63	7	12	63.2	19	9.551	10.534	0.983	-3.510	38.0	1760	2110
5.12E-07	0.192	357.85	7	12	63.2	19	10.031	11.013	0.983	-3.695	64.0	387	1850
4.68E-07	0.273	411.41	7	12	63.2	19	10.534	11.517	0.983	-3.890	109.6	0	2.5

4.2.2.1 Sensitivity Analyses of the Basic Parameters (D_1, m, and St) on the Transverse Cracking

Since some cases reached the maximum cracking 61 months after construction, the analysis will be based on the results obtained during the first 61 month period. Since the three parameters are continuous (as opposed to discrete values of the mix properties dealt with in the next paragraph), multiple regression is used to analyze the data. Figures 4-18 to 4-20 present the plot of transverse cracking versus D_1, m, and St. The plots suggest that:

- m seems to have a nonlinear relationship with transverse cracking.
- The relationship with St is not clear.
- D_1 is insignificant in predicting the transverse cracking.
- There are limiting values of the parameters for which no cracking (under the conditions of the analysis) is expected, i.e., for m > 0.24 or St > 450 psi.

A detailed analysis shows that the variables m, St, and m^2 are statistically significant in predicting transverse cracking at $\alpha = 0.05$; D_1 remains insignificant with all quadratic regression models.

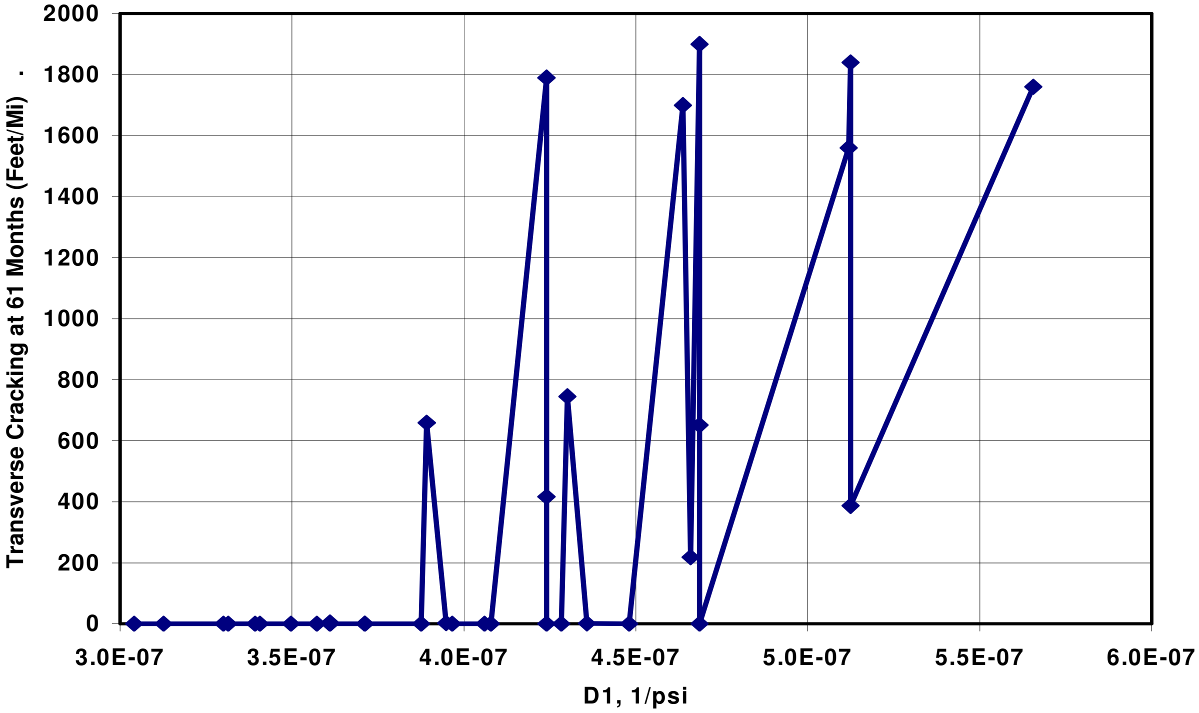


Figure 4-18. Transverse Cracking at 61 Months vs. D1.

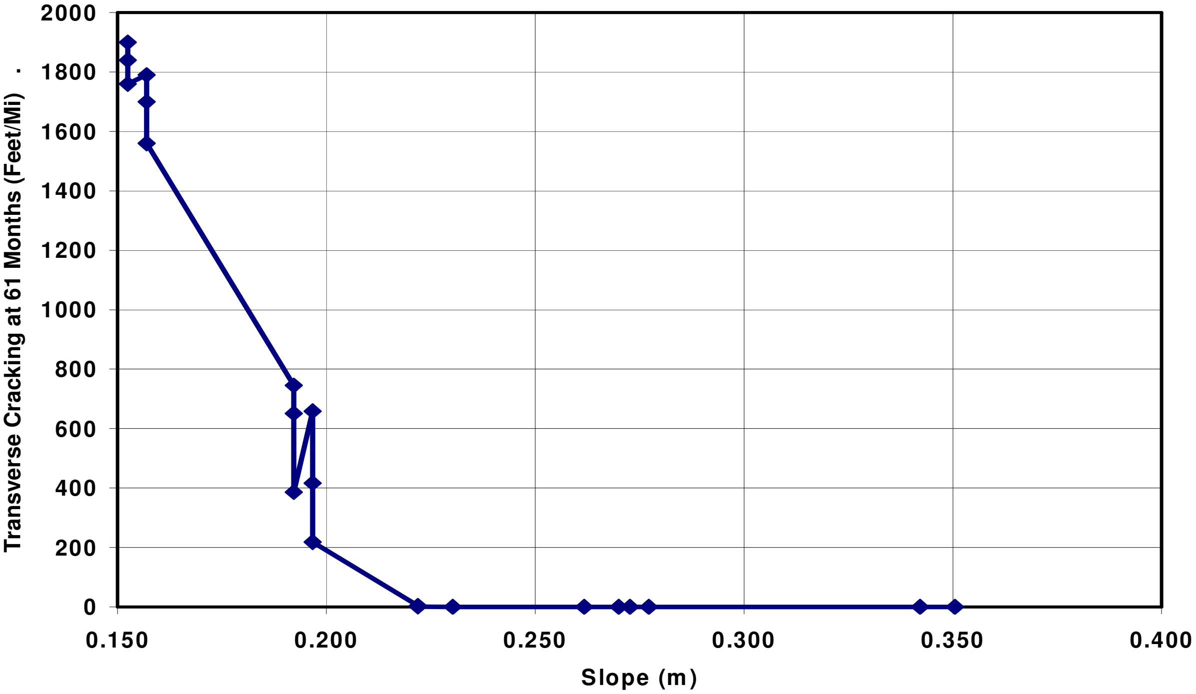


Figure 4-19. Transverse Cracking at 61 Months vs. m.

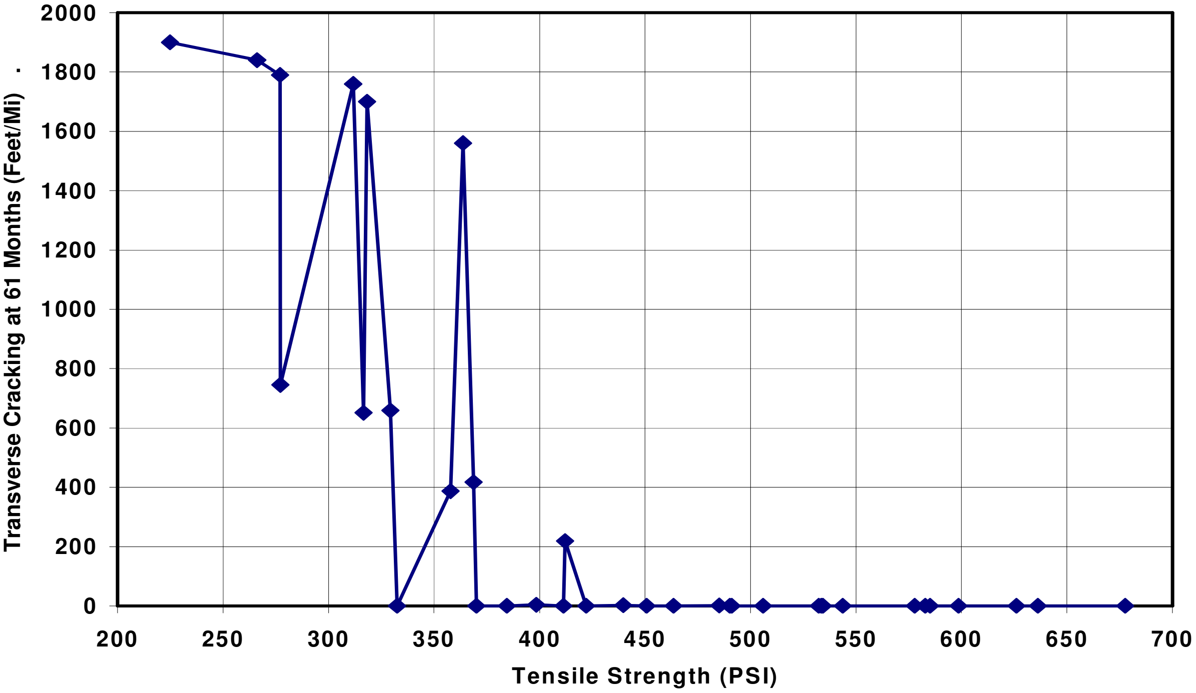


Figure 4-20. Transverse Cracking at 61 Months vs. Tensile Strength - St.

4.2.2.2 Sensitivity Analyses of the Mix and Binder Properties (Va, Vb_{eff}, Diff= A –A_{rtfo}, and Pen_{77}) on the Transverse Cracking

At Level 3 type of analysis, the basic properties D_1, m, and St are computed from the mix and binder properties. The correlation used for the D_1 fracture parameter is:

$$\log(D_1) = -8.5241 + 0.01306T + 0.7957\log(V_a) + 2.0103\log(VFA) - 1.923\log(A_{RTFO})$$

where

T = Test temperature (ºC) (i.e., 0, –10, and –20 ºC)
V_a = Air voids (%)
A_{RTFO} = Intercept of binder Viscosity-Temperature relationship for the RTFO condition
VFA = Void filled with asphalt (%) = $\dfrac{Vb_{eff}}{Vb_{eff} + Va} \times 100$

For the m parameter, the correlation used is:

$$m = 1.1628 - 0.00185T - 0.04596V_a - 0.01126VFA + 0.00247Pen_{77} + 0.001683Pen_{77}$$

where

Pen_{77} = Penetration at 77 ºF = $10^{290.5013-\sqrt{81177.288+257.0694*10^{(A+2.72973*VTS)}}}$

A = Intercept of binder Viscosity-Temperature relationship
VTS = Slope of binder Viscosity-Temperature relationship

The following correlation is used for the tensile strength (S_t in psi) at –10 ºC:

$$St = 7416.712 - 114.016V_a - 0.304{V_a}^2 - 122.592VFA + 0.704VFA^2 + 405.71\log(Pen_{77}) - 2039.296\log(A_{RTFO})$$

The analysis includes two levels for V_a and Vb_{eff} and three levels for Diff and Pen_{77}, as shown in Table 4-5 (see Table 4-4 for the values of the variables).

Table 4-5. Factors Used in the Experiment.

Factors	Levels		
V_a	Low (4)		High (7)
Vb_{eff}	Low (9)		High (12)
Diff (ARTFO, A)	Low (0)	Medium (0.4796)	High (0.9829)
Pen_{77}	Low (38.01)	Medium (63.96)	High (109.56)

The analysis of variance (ANOVA) at α = 0.05 shows that:

- Vb_{eff} and Pen_{77} are the most significant factors. The amount of transverse cracking increases with the amount of binder and the binder viscosity,

- Interaction effects of Vb_{eff}×Va, Vb_{eff}× Pen_{77}, and Vb_{eff}×Diff were found significant. This suggests that the effect of each variable depends on the level of the other variable. For example, the effect of Pen_{77} on transverse cracking is different for each level of Vb_{eff} (see Figure 4-21).
- The effect of aging, expressed via the factor Diff = $A - A_{RTFO}$ was significant, however slightly less than Vb_{eff} and Pen_{77}.

The results of the analysis are more complex to assimilate than those of the basic variables (D_1, m, and St).

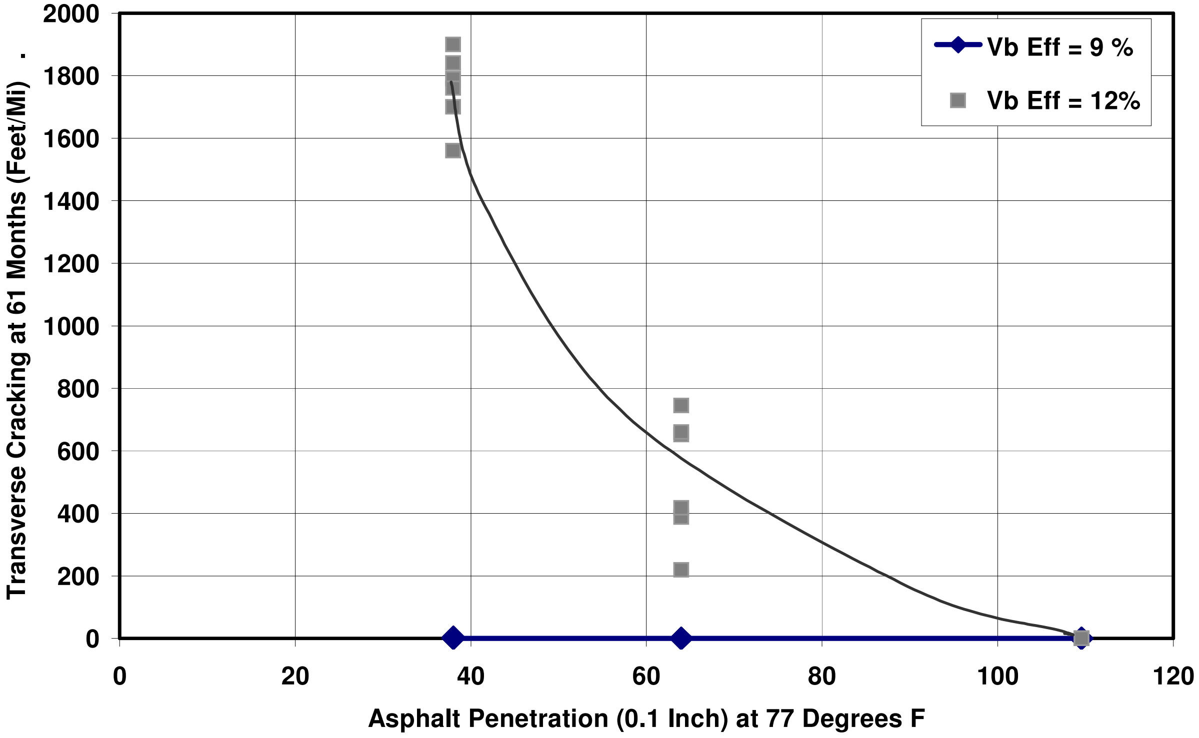


Figure 4-21. Transverse Cracking versus Vb_{eff} and Asphalt Penetration.

4.3 SUMMARY OF FOCUSED SENSITIVITY ANALYSIS

The chapter presents focused sensitivity studies related to environmental effects and thermal cracking. It is found that:

The choice of weather stations can affect the material properties of the materials used in the analysis. Therefore unless the project is located very close to a specific weather station, it is recommended to use three, or at least two, nearby weather stations.

The depth of the water table is an important input parameter only in wetter areas and when the depth to water table is close to the surface (less than 17 feet deep).

The parameter m of the creep curve and the tensile strength St have significant effects on thermal cracking. There seems to be limiting values of the slope m and of the strength St for which no transverse cracking is expected.

CHAPTER 5 - IMPLEMENTATION STRATEGY

5.1 DESIGN EXAMPLES

Two recent pavement design cases are used to illustrate a pilot design using the M-E Design Guide and to evaluate the use of the Guide with TxDOT pavement designs. These design cases are SH 40 (typical highway design) in the Bryan District and SH 114 (perpetual pavement design) in the Fort Worth District. When data were available, they were used directly. When data were not available, as is common in a pavement design where the actual materials are not known until near the actual time of construction, default or typical values were used.

5.1.1 SH 40

The original design was developed by TxDOT using FPS19W and is shown in Figure 5-1. It includes:

1. the layer thicknesses (2 inch HMAC, 18 inch granular base [GB] Class I, and 10 inch lime treated subgrade [LTS] on top of a clayey subgrade);
2. the moduli used in the analyses (500, 70, 35, and 10 ksi for the AC, GB, LTS, and subgrade, respectively), and
3. the cost analysis.

The analysis of potential vertical rise (PVR) calls for a cover of nonswelling material at least 30 inches thick because of the local swelling clay.

The subgrade material in the soil borings is classified as CL (clay with low plasticity) and CH (clay with high plasticity), with an upper liquid limit (LL) of 65 and upper plasticity index of 42, excluding a few results with LL of 102 and PI of 78. If these materials are found close to the subgrade level, they will require special localized treatment. It appears that the design subgrade material is swelling clay (CH). FWD results from the closest highway with available FWD testing (SH 6 frontage road) were analyzed. The results show considerable scatter. However, the analysis of the FWD results for the eastbound lane show a backcalculated subgrade moduli that is quite low. The value is slightly lower than the 10 ksi used by TxDOT in the original analysis. For the analysis using the M-E Design Guide, it was decided to adopt a design value of 8 ksi, which is, coincidentally, also the M-E Design Guide default value for A-7-6 materials. The hot-mix asphalt (HMA) mix design results from the proposed design were provided and the following properties were used in the design to generate a default master curve:

Retained 3/4" sieve = 0%,
Retained 3/8" sieve = 33%,
Retained #4 sieve = 60.3%,
Passing #200 sieve = 6.7%,

Asphalt binder PG 64-22,
Effective binder content = 10.6%,
Air voids = 3.6%, and
Total unit weight = 147.3 pcf.

The M-E Design Guide does not include a special type of material for the lime treated subgrade, so this layer was treated as an upper, stiff subgrade material with an estimated modulus of 22 ksi, which is lower than the 35 ksi used by TxDOT. This can be a lime treated subgrade or a subbase material such as Class III base (A-1-b to A-2-4 material). For the analysis using the M-E Design Guide, it was estimated that the modulus of the base material Class I (A-1-a material) would be 50 ksi if resting on the subbase or lime treated subgrade. This value is higher than the M-E Design Guide default for A-1-a materials but lower than the 70 ksi used by TxDOT.

The functional class of the traffic was estimated to be Truck Traffic Class 10 - mixed truck traffic with about equal percentages of single-unit and single-trailer trucks. TxDOT reported the initial AADT to be 7300 vehicles per day, with 6.8 percent trucks and 4.5 percent annual growth. The total 20 year 18 kip single axle (SA) in the lane was estimated at 1,621,000.

The input necessary to run the M-E Design Guide case is as follows:

- at least 30 inches of nonswelling material cover is required (TxDOT guidelines for this soil);
- clayey subgrade type A-7-6;
- lime treated subgrade or subbase materials, granular base, and HMAC materials available for the construction;
- weather station at Easterwood Airport, Texas; and
- design Level 3 because no specific test results are available.

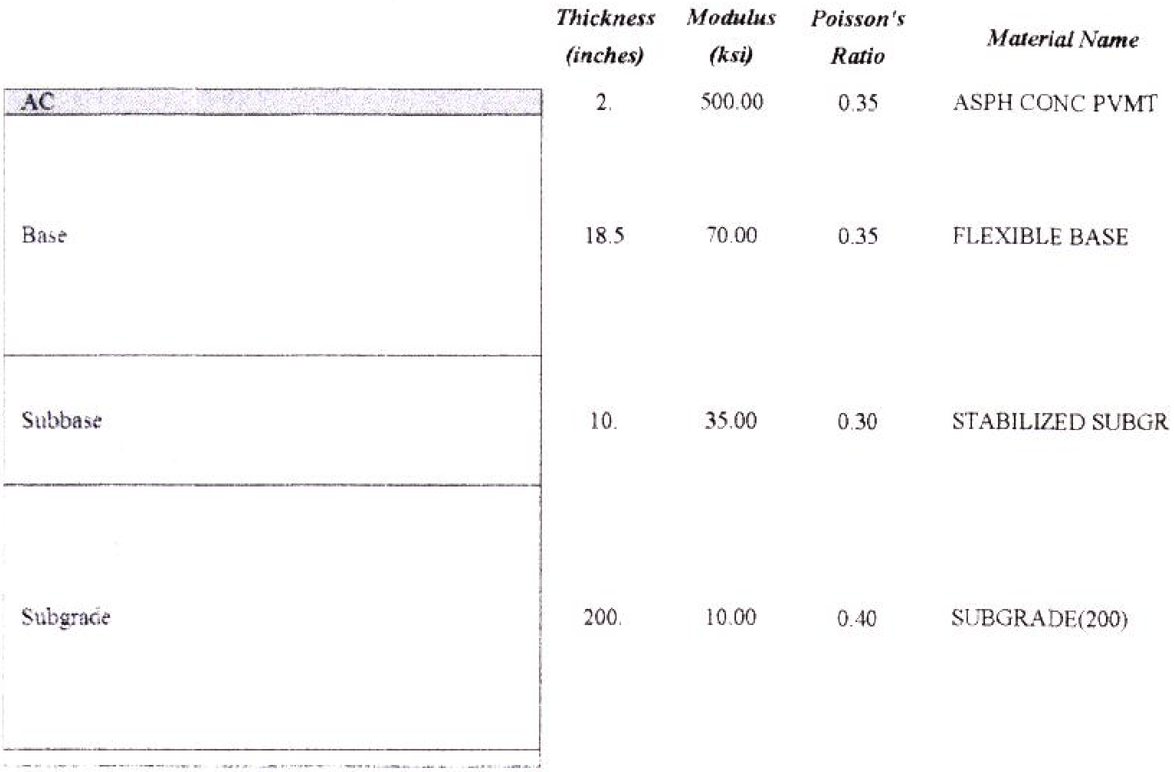
In the first stage, runs were made using a traffic stream containing 18 kip SA only to allow comparisons of the results with the original design. This also reduced the run time from about 30 to about 10 minutes. First, the original design was analyzed to obtain the performance data. The performance results obtained at the end of the design period are presented in Table 5-1. It shows that the critical distress governing this design is the rut depth, which ultimately reached about 0.447 inch at 50 percent reliability. Additional runs were made with the Guide using the material properties generated from the Guide (i.e., granular layers and subgrade moduli lower than assumed in the original design; see values above). The HMAC layer was varied between 2 and 8 inches, the granular layer was assumed at 12 and 18 inches, and the lime treated subgrade varied between 10 and 14 inches (to ensure the 30 inch minimum cover). The results, illiustrated in Figure 5-1, demonstrate that in order to reach a similar or better level of performance than the original design, at least 6 inches of HMAC is needed. The cost of the new design is more than 30 percent higher than the original design. As the fatigue distress is barely triggered, it seems that the HMAC thickness should be adjusted to give less rutting. This suggests that the HMAC thickness should be kept at the minimum thickness of 2 to 4 inches, while increasing the stiffness of the other components. This could be achieved by introducing cement treated base in the design. The thickness of the CTB was kept constant at 8 inches with a resilient modulus of 800,000 psi. The thickness of the base course (an open-graded type should be selected to allow for the best drainage) was set at 6 inches with a resilient modulus of 50,000 psi. Therefore, two more runs were made using 14 and 12 inches of lime treated subgrade (not a granular subbase so that water will not be trapped in the layer) and 2 and 4 inches of HMAC. The results are presented in Table 5-1. In terms of performance, it shows that the optimum design is case 6, with case 8 a close second. However, according to local experiences, case 8 may not be a viable design. For example, if an open-graded (with good drainage properties) base course is not available, this design could not be built. It is worth mentioning that the CTB design was not calibrated in the current version of the Guide. In order to check the design, bending stresses were computed at the bottom of the CTB. This indicated that a modulus of rupture of about 100 psi (or an unconfined compressive strength of about 500 psi) is required. Note that the use of CTB is not included in FPS19 and, therefore, the local engineer could not introduce it in the design.

Some additional comments about the results so far are included below.

- The traffic load is light; therefore, no fatigue cracking is expected.
- The total thickness required to limit the PVR to 1.5 inch is 30 inches. Therefore, any design was modified to provide this thickness of cover over the subgrade.
- The distress level in the original design, at the end of the design period, is high. The rut depth at 50 percent reliability is about 0.45 inch. At 90 percent reliability, the predicted rut depth is 0.58 inch.
- Other possible design cases, such as full depth HMAC, were not explored because of the PVR restriction.

The distress prediction was refined and re-analyzed by using a more complete traffic distribution, assuming a functional class of 10. The analysis was made for the original design and design cases 6 and 8 in Table 5-1. The predicted distresses, at two reliability levels, 50 and 90 percent, are shown in Table 5-2. It shows that the two alternate designs obtained using the Guide are similar in both performance and price. The computed rut depth of 0.38 and 0.5 inch, at reliability levels of 50 and 90 percent, respectively, are both acceptable. The original design seems to use relatively high moduli for the granular base and lime treated subgrade. The material properties used in FPS19W need to be verified.

It is worth noting than in this analysis using the M-E Design Guide, actual backcalculated values from in-service LTPP pavements were utilized to determine the modulus used in the analysis. Local TxDOT representatives used values with which they were quite comfortable and which have proven to give reasonable results. These two different approaches, using two different design programs, with different inputs and different moduli values, gave different results. The analysis was run using the M-E Design Guide with the TxDOT values. It is included in Table 5-2.



	Thickness (inches)	*Modulus (ksi)*	*Poisson's Ratio*	*Material Name*
AC	2.	500.00	0.35	ASPH CONC PVMT
Base	18.5	70.00	0.35	FLEXIBLE BASE
Subbase	10.	35.00	0.30	STABILIZED SUBGR
Subgrade	200.	10.00	0.40	SUBGRADE(200)

Figure 5-1. Proposed Pavement Design from FPS19W.

Table 5-1. Analyses Using 18 kip ESAL at 50 Percent Reliability Level.

	Thickness (in.)				Performance					
Design Case	HMAC	GB	CTB	Lime Treated Subgrade or Subbase	Percent Alligator Cracking	Total Rut (in.)	IRI (in./mi)	Ride	Longitudinal Cracking (ft/mi)	Initial Cost * ($/SY)
Original	2.0	18.0	-	10.0	0.004	0.447	93.3	3.8	0.47	20.67
1	2.0	18.0	-	10.0	0.022	0.533	117.5	3.5	0.88	20.67
2	4.0	18.0	-	10.0	0.528	0.482	97.7	3.7	0.02	24.56
3	6.0	18.0	-	10.0	0.174	0.416	96.5	3.7	0.32	28.44
4	4.0	12.0	-	14.0	0.613	0.490	96.8	3.7	0.02	21.00
5	6.0	12.0	-	12.0	0.205	0.420	96.5	3.7	0.24	24.34
6	8.0	12.0	-	10.0	0.072	0.365	96.4	3.7	0.03	27.67
7	2.0	6.0	8.0	14.0	0.008	0.399	117.3	3.5	2.51	24.11
8	4.0	6.0	8.0	12.0	0.242	0.386	117.3	3.5	0.02	26.89

* CTB estimated at $50/cy.

Table 5-2. Analyses Using Actual Traffic Distribution and Preliminary Calibration Factors.

	Thickness (in.)				Performance						
Design Case	HMAC	GB	CTB	Lime Treated Subgrade or Subbase	Percent Alligator Cracking	Total Rut (in.)	IRI (in./mi)	Ride	Longitudinal Cracking (ft/mi)	Initial Cost * ($/SY)	Reliability Level (%)
Original	2.0	18.0	-	10.0	0.002	0.398	93.3	3.8	0.07	20.67	50
					(2.22)	(0.526)	(125.02)	3.3	(408.1)		(90)
6	8.0	12.0	-	10.0	0.045	0.368	96.4	3.7	0.17	27.67	50
					(1.42)	(0.495)	(128.14)	3.2	(515.0)		(90)
8	4.0	6.0	8.0	12.0	0.190	0.387	117.3	3.5	0.00	26.89	50
					(1.40)	(0.516)	(149.05)	3.0	(281.7)		(90)
M-E Using TxDOT	2.0	18.0		10.0	.003	.433	93.4	3.8	0.13	20.67	50%

* CTB estimated at $50/cy.

5.1.2 SH 114

FWD measurements were obtained along the existing roadway. MODULUS 5.1 was used by Dr. A. J. Wimsatt (Pavement Engineer, Ft. Worth District, TxDOT) to obtain a median modulus of the subgrade of 9.1 ksi. The field investigation conducted by TERRA-MAR consultants indicated that the "upper soil strata (which might be used as the pavement subgrade) generally consist of soft to very stiff clays, sandy clays, and clayey sandy gravels of moderate to high plasticity." The value of 9.1 ksi chosen for the subgrade corresponds to the materials described. PVR calculations led to the conclusion that "the depth of coverage of nonswelling material to reduce the PVR to 1.0 inch under dry conditions is estimated to be 24 inches at borings B-2, B-3 and B-5."

Using FPS19W, Dr. Wimsatt arrived at the following pavement structure that is expected to perform for at least 19 years before an overlay is needed: 2 inch stone matrix asphalt concrete (SMA), 2.5 inch Superpave 19 mm maximum aggregate size HMAC, 13 inch Superpave 25 mm maximum aggregate size HMAC, and 3 inch Superpave 19 mm maximum aggregate size HMAC with 2 percent air voids. The top 8 inches of the subgrade will be lime treated. In the TxDOT design, the lime treated subgrade was conservatively assumed to have the same modulus as the subgrade. TxDOT assumed that same low value of the modulus for the bottom 3 inch layer of HMAC, which also leads to a conservative design. It is worth mentioning that the FPS19W pavement design software was not calibrated for this type of structure.

The Guide was used to analyze the proposed pavement structure and the significance of neglecting the lime treated subgrade and the bottom 3 inch HMAC layer. The runs were made using Level 3 type of analysis, i.e., default input variables were used, except for the following data:

- Initial AADTT = 2050 trucks/day in two directions.
- Traffic growth = 6.5% compound function.
- Vehicle class distribution = TTC1, predominantly single-trailer trucks.
- Weather station at Waco Regional Airport, TX.
- The properties of the HMAC layers are summarized in Table 5-3. The composition of the SMA and Superpave 19 mm HMAC were assumed, as no mix design was available.
- The modulus of the lime treated subgrade was set at 17 ksi. The modulus of the natural subgrade was set at 9 ksi. Both were assigned representative values, not affected by EICM.
- The calibration factors obtained in the preliminary calibration were implemented.

The results of the analyses are summarized in Table 5-4, for 50 and 90 percent reliability. It is clearly seen that:

1. Ignoring the lime treated subgrade layer did not affect the performance (cases 1 and 2). This result suggests that full-depth HMAC structures behave like rigid pavement in being less sensitive to small changes in the support.

2. There is a jump in the predicted IRI when the lime treated layer is deleted (cases 1 and 2). This may be attributed to using different models for predicting IRI for the different types of structures.

3. The full-depth HMAC structure is resistant to fatigue in terms of alligator or bottom-up cracking. Even the 12 inch structure (case 4) did not develop alligator cracking. Therefore the crack resistant layer at the bottom of the thick full-depth structure may not be required. This needs to be further evaluated after local calibration of the Guide.

4. The 14 inch HMAC over 8 inch lime treated subgrade, or the 15 inch HMAC over natural subgrade structure, would perform for at least 20 years before an overlay was needed. This seems to indicate that the original structure of 20.5 inches may be over-designed. This also needs to be further evaluated after local calibration of the Guide (and for meeting PVR requirements).

Table 5-3. Properties of the HMAC Layers.

Property	SMA	Superpave 25 mm ACP	Superpave 19 mm ACP
Effective Asphalt Content (%)	10.6	10.1	11.0
Air Voids (%)	3.6	4.0	3.0
Total Weight (PCF)	147	150	148
Percent Retained on 3/4" Sieve	0	8	0
Percent Retained on 3/8" Sieve	33	30	20
Percent Retained on #4 Sieve	60	54	60
Percent Passing #200 Sieve	6.7	3.3	6.0
Binder Grade	76-22	64-22	64-22

Table 5-4. Summary of Predicted Distress for SH 114 After 20 Years of Traffic.

Case	Structure	Reliability (%)	Longitudinal Cracking (ft/mi)	Alligator Cracking (%)	AC Rutting (in.)	Total Rutting (in.)	IRI (in./mi)
1	2" SMA, (11+3)" HMAC =16" on 8" LS subgrade	50 (90)	0.10 (450.3)	0.02 (0.99)	0.213	0.288 (0.403)	129.9 (161.7)
2	2" SMA + (11+3)" HMAC =16" on natural subgrade	50 (90)	0.04 (371.8)	0.02 (1.06)	0.210	0.281 (0.395)	150.0 (181.9)
3	2" SMA + 13" HMAC = 15" on natural subgrade	50 (90)	0.01 (308.1)	0.08 (1.65)	0.207	0.282 (0.396)	150.0 (181.9)
4	2" SMA + 10" HMAC =12" on natural subgrade	50 (90)	0.01 (314.2)	0.23 (3.07)	0.312	0.403 (0.538)	150.2 (182.0)
5	2" SMA +12" HMAC =14" on 8" LS subgrade	50 (90)	0.01 (300.1)	0.08 (1.71)	0.206	0.291 (0.406)	129.9 (161.8)
6	4.5" SMA+13" HMAC = 17.5" over 11" lime treated, natural subgrade	50	0.00	0.04	0.18	0.256	129.9

As noted earlier, the use of different moduli with different design methodology gave somewhat different results. Case 6 above uses the M-E Design Guide with TxDOT values for modulus. An interesting anomaly to this part of the study is that in one instance our values were more conservative and in the second case were less conservative.

5.2 PERFORMANCE CRITERIA LIMITS

The M-E Design Guide allows the user to enter the maximum amount of each distress desired at the end of the performance period. This value is not used in any calculation but is used to plot values on the graphical output of the performance of the pavement for each distress. The following values are suggested starting values.

5.2.1 Performance Criteria for HMAC Pavements

The data in the TxDOT pavement management information system (PMIS) were queried to determine the distribution of distresses. Figure 5-2 illustrates the distribution of longitudinal cracking. This distribution is in ft/100 ft, while the M-E Design Guide requires ft/mi; 2000 ft/mi is approximately 40 ft/100 ft. Figure 5-3 illustrates the distribution of alligator cracking by percent. Since the M-E Design Guide makes no allowances for patching, which removes the distress, slightly higher values are suggested. Table 5-5 contains the suggested starting values, by expected traffic volume. Traffic and truck traffic volume was used instead of other classifications because this describes the need for reliability better than other designations.

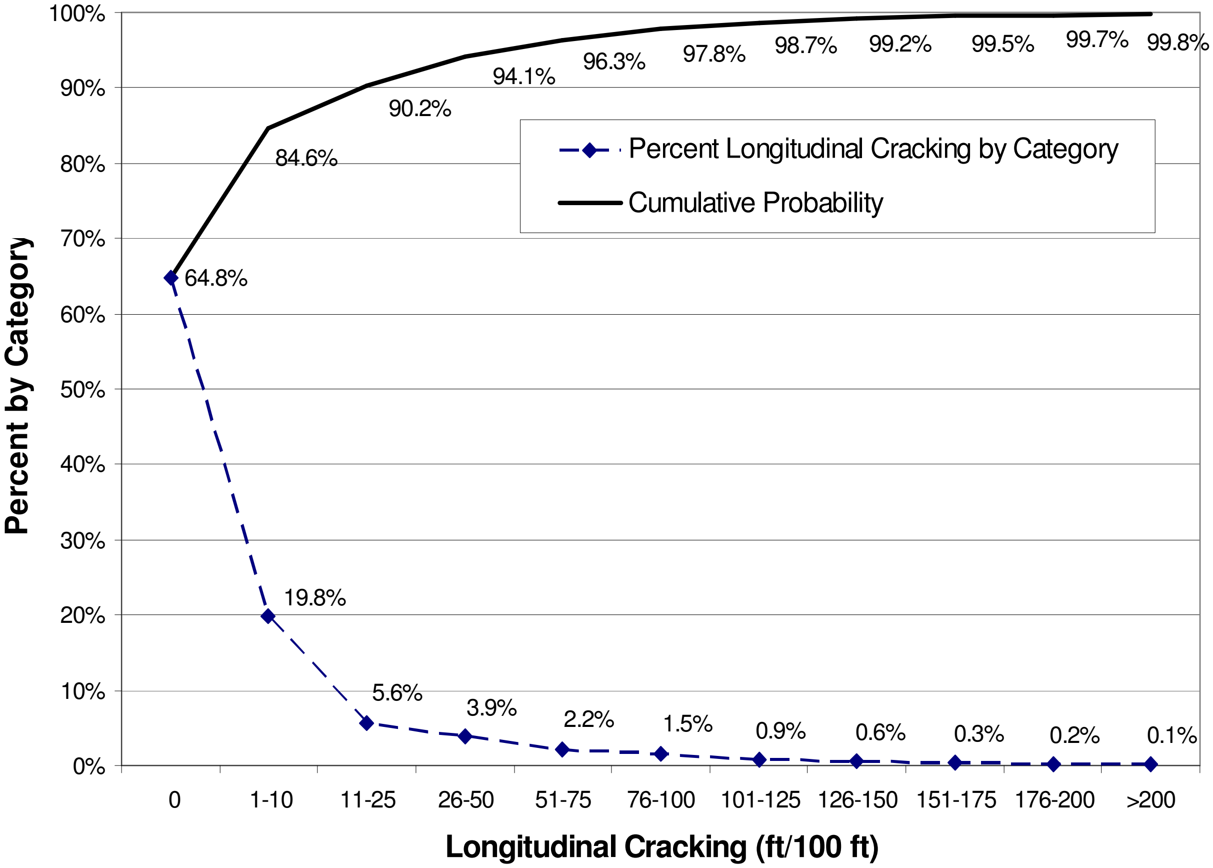


Figure 5-2. Distribution of Longitudinal Cracking from PMIS.

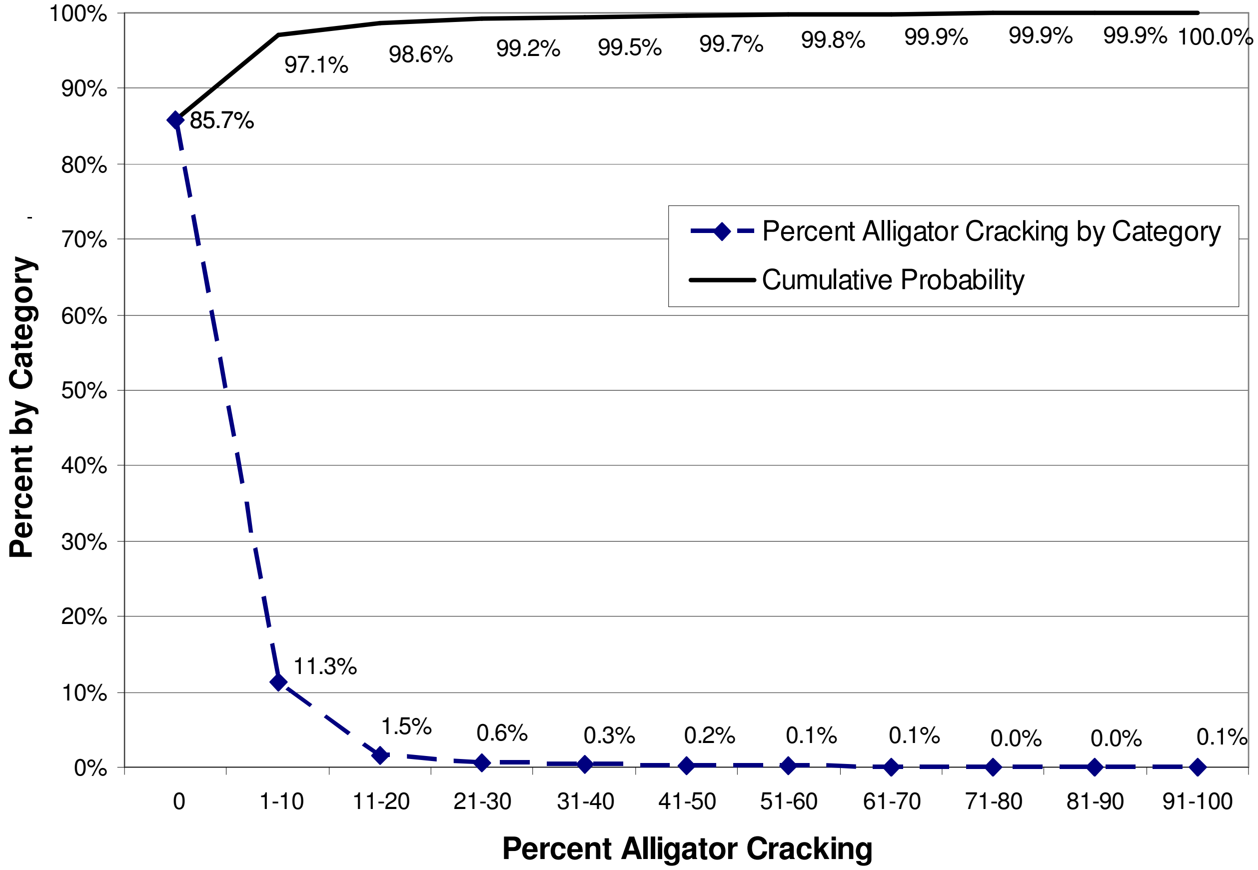


Figure 5-3. Distribution of Alligator Cracking from TxDOT PMIS.

Table 5-5. Proposed Performance Criteria for HMAC Pavements.

Distress Type	Reliability (Percent)	Light Traffic (≤2×10^6 ESALs)	Medium Traffic (>2×10^6 and <15×10^6 ESALs)	Heavy Traffic (≥15×10^6 ESALs)
Terminal IRI (in./mi) /Ride Score	50	200/2.3	170/2.6	135/3.1
	90	270/1.5	215/2.1	170/2.6
Total Rutting (in.)	50	0.4	0.35	0.3
	90	0.5	0.45	0.4
Longitudinal Cracking (ft/mi)	50	2000	1000	1000
	90	3000	1500	1500
Alligator Cracking (percent)	50	10	8	5
	90	25	17	10
Thermal Cracking	50	No suggestions. No cracking was predicted.		
	90			

5.2.2 Performance Criteria for CRCP Pavements

CRCP performance is composed of punchouts and IRI only. In addition, CRCP is usually only found on the higher volume routes. Therefore, the suggestions for CRCP are less than 20 po/mi and an IRI less than 200.

5.3 STRATEGY FOR IMPLEMENTATION

Chapter 6 will deal with whether TxDOT should implement the M-E Design Guide. This section deals with how it should be implemented, assuming that the decision is made to implement. The background and expertise levels required for pavement design using the M-E Design Guide are relatively high. These levels of expertise cannot be achieved in a few years of on the job training. It may be that in order to properly and fully implement the M-E Design Guide, TxDOT may have to create new specialty positions for engineers dedicated to materials (laboratory) and pavement design. It would be of tremendous benefit to TxDOT to return the Pavement Engineer position to a proud position that engineers look forward to being a part of.

The Guide should not be used by TxDOT until (1) the final version is released, (2) preliminary calibration (similar to the one presented in Chapter 3) is made, and (3) training is completed. A two-stage implementation is recommended. At the first stage, only the dedicated engineers who received the advanced training and are involved in the local calibration may use the Guide, in parallel with the current design method (FPS19W). At the end of the local calibration, TxDOT will be trained to use the Guide, exclusively. The reason that a quick and complete conversion to the new procedure is required is that the use of empirical design procedures in parallel with the Guide may be confusing because it will lead to different designs without any mechanistic justification, and the engineer may not be able to solve the dilemma. This confusion will cause uncertainty in the pavement engineers and they will most likely revert back into the well-known procedure and eschew any attempts to bring them forward.

The implementation was separated into five different tasks: training, laboratory, field, calibration (and validation), and additional studies (see Table 5-6). Each of these tasks was subdivided into subtasks. The following is a detailed description of the subtasks.

5.3.1 Training

The training of the staff dealing with pavement design, evaluation, and rehabilitation is the crucial task in the implementation. It must be compulsory for every engineer (either from TxDOT or from a consulting firm) who will use the Guide. The training is subdivided into two levels: basic and technical.

1. <u>M-E Design Guide Basic Training</u>: The department should begin to train some of the senior pavement engineers who are users of the current design method (FPS19W). This type of training should be provided by the FHWA Design Guide Implementation Team (DGIT). All pavement engineers, including the dedicated personnel from the advanced training, should attend. Furthermore, meetings of the Design Guide Users Group

(organized by the dedicated engineers) should be scheduled every six months, to update the group on any changes, additions, availability of databases, etc., and to work through problems encountered during the routine operation of the program.

2. Advanced Technical Training: The department should have a few (about 10) dedicated engineers who will be specialized in the field of pavement design. These personnel will be responsible for the implementation of the Guide over the next five years. Therefore, they should receive advanced training that will allow them to comprehend the mechanistic models included in the Guide. The training should include:

    a. Fundamentals of soil and pavement engineering, including moisture and binder-density relationships, gradation, Atterberg limits, definition of degree of saturation, air void, voids in the mineral aggregate (VMA), effective volume of binder, water flow, moisture suction curves, etc.
    b. EICM: Heat and water flow basics, description of the EICM, from the weather stations to the prediction of temperatures and moisture content.
    c. Traffic: Traffic classification, trucks and axles distributions, traffic growth, special configuration.
    d. Material characterization:
        i. Introduction to elasticity, plasticity, visco-elasticity, and visco-plasticity.
        ii. Unbound material: Resilient modulus testing and values, moisture effects, permanent deformation characterization, testing, definitions of ALPHA and GNU, and other equations used in the Guide.
        iii. Cement stabilized material: Properties, modulus, modulus of rupture, fatigue.
        iv. Asphalt binder: Viscosity, aging, shear modulus, PG grade.
        v. AC: Dynamic modulus, testing, construction of a master curve, regression equations.
    e. Field testing and analysis:
        i. FWD testing and back-calculation of moduli.
        ii. GPR measurements and analyses.
        iii. DCP, CBR, etc.
    f. Pavement response system:
        i. Linear elastic multi-layer.
        ii. Finite elements.
    g. Damage accumulation algorithms for fatigue, rutting, longitudinal cracking, thermal cracking, and roughness (IRI).
    h. Reliability.

The basic training should be organized once and be given by specialized professionals.

5.3.2 Laboratory

TxDOT does not yet have the proper equipment for characterizing the pavement materials in terms of resilient or dynamic modulus, as required by the Guide. Testing services may be provided by research facilities or private companies, at least until new equipment is purchased. A current price quote on the equipment required was obtained as part of this project. The cost for the equipment, which includes installation and some training, was approximately $147,000 per installation. It is recommended to equip the central and few district laboratories (where the dedicated engineers are located). This will permit testing of more material types, extending the professionalism to all parts of the state and generating professional interest and discussions. The National Cooperative Highway Research Program (NCHRP) is conducting several studies for evaluating different types of equipment. A TxDOT engineer should be dedicated to preparing the specifications and supervise the purchasing order.

The personnel should be trained to conduct the tests on unbound base, subbase and subgrade materials, lime treated subgrade soils, cement treated bases, and AC mixtures.

Finally, the laboratories must produce results that could be used in the Guide. These results should be stored in databases and made available to all districts. In the first phase, the laboratories will test materials from projects and from sections used in the calibration/validation of the Guide.

5.3.3 Field and Forensic Studies

Forensic studies need to be conducted in the sections chosen for the calibration/validation stage. The field studies should include:

1. FWD and GPR measurements and analyses.
2. Cutting trenches in order to:
    a. measure and verify layer thicknesses,
    b. measure the rutting in each layer. This is required for calibrating the permanent deformation models of the different layers, and
    c. measure the moisture distribution (and if possible the suction) for validating the EICM predictions.
3. Take undisturbed and disturbed samples for laboratory testing.

5.3.4 Calibration and Validation of the M-E Design Guide.

Calibration and validation should follow the recommendations from NCHRP Project 9-30. An absolute minimum of about 40 sections will be needed for calibration and validation, using the jackknifing statistical procedure identified in that report. Once the sections are identified and the data collected, it may become necessary to supplement the initial number of sections. These sections should be chosen to represent a variety of climatic zones, traffic composition, and material types. Detailed data should be collected from available sources and from sections 5.3.2, 5.3.3, and 5.3.5. It should include:

1. past traffic;
2. pavement, layer thicknesses, material properties; and
3. past and actual distress survey.

5.3.5 Additional Studies

1. Calibration and Validation Database. Described earlier.

2. Projection of Truck Traffic Distribution. The design of new and rehabilitated pavements is based on projections of future traffic, not the current configuration and traffic level. Since the load and axle configuration are very important for the design, it seems very important to forecast the composition of future traffic load. It seems that more tandem axles are presently used than were in service a few decades ago. Will these tandem axles be replaced by tridems and quads?

3. Database. Enhance and continuously update the database that contains default values for traffic and material properties.

4. Expert System. Develop an expert system that will guide the engineer in choosing initial structures and materials. The system should be based on the M-E Design Guide and local experience. One scenario of such a system will be to develop a set of input files with different pavement structures that will run in the batch mode of the M-E Design Guide and with a simplified traffic data (for example, using the design load axle concept). The system would generate a summary for the engineer who will choose few structures to run (possibly also in batch mode) using the Guide. Such a system will make use of the Guide much more simple and attractive.

5. Lime Treated Soil Tests. Typically, very few tests are conducted on a lime treated soil. Since the M-E Design Guide does not specifically identify this type of layer, a full set of tests needs to be conducted for many samples. All data items identified for a base or subgrade soil must be tested.

6. Nontypical Layers. Data from the nontypical layers, such as the rich bottom layer in the perpetual pavement design, must have the full battery of tests conducted to ensure that the values being used are appropriate.

7. Other. As the Guide is updated with newer models and procedures, more research will be needed.

Table 5-6. Outline of Implementation Steps.

A. Training	B. Laboratory	C. Field and Forensic Studies	D. Calibration and Validation	E. Additional Studies
M-E Design Guide Basic Training Advanced Technical Training	Obtain needed equipment Training on testing Develop databases of material properties	FWD and GPR Trenches for: layer thickness, layer contribution to rutting, moisture distribution for EICM predictions Materials for lab testing	Select sites and collect data from available sources and from B, C and E on: traffic pavement distress Perform local calibration	Projection of truck traffic distribution Default values for traffic, material properties Guidance on selecting pavement sections, layer thicknesses

CHAPTER 6 - SUMMARY AND CONCLUSIONS

6.1 SHOULD THE M-E DESIGN GUIDE BE IMPLEMENTED IN TXDOT

6.1.1 Is it "Better"

The M-E Design Guide is a tremendous step forward in pavement design. The mechanistic concepts embodied in the mechanistic-empirical design program, the incorporation of climatic effects, transfer functions of distress, expansion of the traffic stream, and axle load distribution concept are the best that current thinking in the pavement community has to offer. In addition, the manual that comes with the Guide is tremendous in its breadth and scope as it walks the user through the concepts and details of pavement design.

The M-E guide is sensitive to the variables we would expect such as grade of AC, layer gradations, and thicknesses, etc., and to many variables that are not usually considered such as elevation, latitude, surface shortwave absorptivity, and many others. Section 2.3 has a more complete list and the appendices list all variables and detail their impact.

The guide has been designed to be modular so that new models and concepts can be incorporated into the existing framework. Table 6-1 compares the Guide to current TxDOT methods.

6.1.2 Should TxDOT Implement the M-E Design Guide

While the above discussion of the Guide is all true, the Guide is very complicated, requires considerable training, has an unnecessary number of inputs for TxDOT, and does not handle some of the more common materials used by TxDOT. The following is a list of problems that would be encountered in a statewide implementation.

6.1.2.1 Seal Coat Design

Certainly the biggest drawback is that the guide does not consider seal coats. Since seal coat pavements represent 44% of the network (from PMIS database for 2003), this is a serious drawback. The mechanistic part of the design could not be easily modified to handle this.

6.1.2.2 Lime Treated/Modified Layers

The subgrade in most parts of Texas is relatively weak and unstable. Through lime treatment or modification, a working platform is created. The properties of these layers required by the guide are not well known. Substantial testing of these layers is required.

Table 6-1. Comparison of M-E Design Guide to TxDOT Design Methods.

Category	Rating	Description
Traffic	Superior	Axle load distribution is much more accurate than ESAL, but difficult to characterize.
Climate	Superior	Actual weather better than FPS19W district temperature constant. Easy to use.
Materials Characterization	Much Better	Much better than single modulus for each layer. No seal coat design. Better for CRCP. More involved, but not better for rehabilitation
Distress Models	Much Better for HMAC No Spalling for CRCP	HMAC has five distresses. No spalling.
Ease of Use	Much Worse	Does not “design” pavements.
Required Data	Much Worse	TONS!! Not all are sensitive.
Sensitivity to Inputs	Very Sensitive	Very sensitive.
Training Required	Much More	Much, much more required.
Understanding of Concepts	Much Harder	Much harder to understand
Accuracy	Currently Mixed	Lots of confidence in current methods.

6.1.2.3 Data Required

There are well over 100 separate inputs, many of which, such as saturated hydraulic conductivity, are not values typically encountered by materials or pavement engineers. Assembling the data required to run this program will take considerable time. Perhaps more importantly, many of the values which have a significant impact on the pavement design will not be known until during or after construction. For example, the specification for material is known well in advance of the project and defines the range of acceptable values. Although this limit is sometimes breached, in general it will define the outer limits of the expected values. The mix design is not usually known until some months before construction and further narrows the range, but the actual value will not be known until the material is placed, and can vary throughout the project. Because of these ramifications, the design can become complicated.

6.1.2.4 Training Required

Training on FPS19W, including the Modulus program, is two and a half days of training. For the new Guide this will be expanded considerably. A minimum of one week will probably be required, assuming the person being trained is an experienced pavement or materials engineer.

6.1.2.5 Computational Time

While somewhat of a minor issue, the Guide takes nearly 40 minutes to run, after all of the data has been input. Input of the data can take 10 to 20 minutes, making the process somewhat lengthy. Faster computers and newer versions may eliminate this minor irritation.

6.1.2.6 Pavement Design

While called a design guide, the program really only evaluates a proposed design. Chapter 5 described some proposed methods to deal with this problem, but currently there is no real way to convert the program into something that would suggest layer types and thicknesses.

6.2 RECOMMENDATIONS

For these and the reasons listed above, the recommendation is to not implement the M-E Guide as a replacement for the current design methods. Future versions that address the problems listed above could make the Guide more palatable. As stated above, there are many things the Guide does extremely well, and if some of the deficiencies can be corrected, the decision could be revisited. If the source code were made available, some corrections could be made in-house. That is, some portions of the data entry could be defaulted, bypassing the need to enter that data and leaving it invisible to the user. Values specific to TxDOT could be written into the help functions and suggested values would be readily available.

The Guide would be an excellent resource for forensic evaluations to compare the as-built values to the proposed values and determine the impact of out of specification materials.

Another wonderful application to which the Guide is perfectly suited is in the area of evaluating new materials and designs, including steel placement, modified asphalts, well draining bases, etc. The only entry for FPS19W is the modulus of the material. If a new material has some unique properties, such as very low temperature susceptibility, the impact of that property on the theoretical performance can be evaluated.

Although not recommended for routine design work in Texas, the Guide should certainly be considered for high-end pavement designs. This should include perpetual pavements (see Section 5.1.2) and high end concrete pavements. There is also the tremendous potential to use the M-E Design Guide when comparing alternate designs.

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APPENDIX A

CALCULATION OF MEAN CRACK SPACING AND PROBABILITY OF OCCURRENCE OF K-TH CRACK SPACING AS A FUNCTION OF AGE

APPENDIX A: CALCULATION OF MEAN CRACK SPACING AND PROBABILITY OF OCCURRENCE OF K-TH CRACK SPACING AS A FUNCTION OF AGE

The following expression can be used to predict the mean crack spacing ($\bar{L}$) using a single layer of steel:

$$\bar{L} = \frac{\left\{f_t - \sigma_{env\,ki}\right\}}{\frac{f}{2} + \frac{U_{mi} P_b}{c_{1ki} d_b}}$$

where

$\bar{L}$ = Mean crack spacing (inch, design average crack spacing)

f_t = Concrete tensile strength

f = Subgrade friction coefficient

$U_{m\,i}$ = $0.0020 k_{1\,I}$ (Peak Bond Stress for age increment *i*, psi)

$k_{1\,i}$ = $(0.1172 f'_{c\,i})*1000$

$c_{1\,ki}$ = First bond stress coefficient computed for each progressive seasonal time increment *i*

$c_{1\,ki}$ = $0.577 - 9.499\text{ e-}09 \frac{\ln \varepsilon_{tot-\varsigma i}}{\left(\varepsilon_{tot-\varsigma i}\right)^2} + 0.00502 L_k (\ln L_k)$

L_k = k^{th} crack spacing, inch

$\varepsilon_{tot-\varsigma\ i}$ = Total strain at the depth of the steel for the time increment *i* on seasonal basis (typical range = 150 to 600 microstrains)

P_b = Percent steel, in fraction

d_b = Reinforcing steel bar diameter, inch

$\sigma_{env\ ki}$ = $C_{ki} * s_{0\,i} * \left(1 - \frac{2\zeta}{h_{PCC}}\right)$ (Environmental stress in the PCC at the depth of the steel in longitudinal direction)

where

h_{PCC} = PCC slab thickness, inch

ζ = Depth to steel, inches (Note: if depth to steel is half of slab thickness, $\sigma_{env\,ki} = 0$)

C_{ki} = $1 - \frac{2 \cos\lambda \cosh\lambda (\tan\lambda - \tanh\lambda)}{\sin 2\lambda \sinh 2\lambda}$ (typical range for C is 0 to 1.043)

λ_{ki} = $\frac{L}{\sqrt{8}\ell}$

ℓ_i = $[(E_{PCC\,i} * h_{PCC}^3)/(12*(1-\mu_{PCC}^2)*k_i)]^{1/4}$ (Radius of relative stiffness (25 to 60 inches))

$E_{PCC\,i}$ = Elastic modulus of PCC for time increment *i*, psi

h_{PCC} = Slab thickness, inch

μ_{PCC} = Poisson's ratio for PCC

k_i = Modulus of subgrade reaction (k-value) for time increment *i*, pci

$\sigma_{0\,i}$ = $\dfrac{E_{PCCi}\varepsilon_{tot-\Delta i}}{2(1-\mu_{PCC})}$ Typical range for σ_0 is 0 to 300psi (Westergaard nominal stress factor based on combination of seasonal- and age-dependent parameters)

μ_{PCC} = 0.15 (Poisson's ratio)

$E_{PCC\,i}$ = Concrete modulus of elasticity for age increment *i*, 3 to 5 million psi

$\varepsilon_{tot\text{-}\Delta\,i}$ = $\alpha^*\ \Delta t_{eqv\,i} + \varepsilon_{\text{¥}} * \Delta(1 - rh_{PCC}{}^3)_{eqv}$ (see Table A-1 for determination of $\Delta(1 - rh_{PCC}{}^3)_{eqv}$) (Equivalent total strain difference between the pavement surface and bottom for user-defined season *s*)

Table A-1. Determination of $\Delta(1 - rh^3)_{eqv}$.

Case Number	Climatic Zone and Ambient Humidity Range	Equation
1	DNF, 10 to 50%	$0.0008\times(h_{pcc})^2\quad 0.0327\times(h_{pcc})+0.3754$
2	WF, WNF 50 to 95%	$0.0028\times(h_{pcc})^2\quad 0.107\times(h_{pcc})+1.4292$
3	DF 0 to 95%	Average of case 1 and 2

α_{pcc} = Coefficient of thermal expansion

$\varepsilon_{\text{¥}}$ = $1210\quad 880y$ (Ultimate drying shrinkage)

y = $(390\,z^{-4} + 1)^{-1}$

$$z = \left[\left(1.25\sqrt{a/c}+0.5(g/s)^2\right)\times\left(\frac{1+s/c}{w/c}\right)^{1/3}\times\sqrt{f_c'}\right]-12, \qquad z\geq 0$$

where

a/c = Aggregate-cement ratio

g/s = Gravel-sand ratio

s/c = Sand-cement ratio

w/c = Water-cement ratio

f_c' = 28 day compressive strength in ksi

Δt_{eqv} = Equivalent temperature or user-defined season to be determined, as noted in Table A-2.

Table A-2. Determination of Dt_{eqv}.

Case Number	Ambient Temperature Range (°F)	Pavement Surface Temperature Range (R_o)	Correction Factor (CF)	Δt_{eqv}
1	20 to 40	21.5	1.000 0.565×(h_{pcc}) + 0.116×(h_{pcc})× SQRT(h_{pcc}) + 0.685× SQRT(h_{pcc})	(R_o EXP(h_{pcc}/ 12× SQRT(2p/g))× R_o) /2/CF
2	40 to 60	23.4	"	"
3	60 to 80	25.7	"	"
4	80 to 100	30.1	"	"

The strength of the bond between the coarse aggregate and the paste at an early age has a significant effect of the development of the crack pattern in a CRC pavement system. Apparently, the early bond strength of the coarse aggregate is primarily mechanical in nature; however, physical adhesion may play some role. From a mechanical standpoint, crushed aggregates typically manifest greater bond strengths at an early age than rounded aggregates. In terms of cracking patterns, smooth river gravel coarse aggregate concrete mixtures typically develop cracking patterns of greater crack density and at closer cracking intervals than those made with crushed coarse aggregates. Because of the difference in bond strength of the coarse aggregate and the difference in cracking behavior, the percentage of reinforcement should be reflected in the type of coarse aggregate used in the concrete. River gravel concrete should require less steel reinforcement than a CRC pavement made with limestone concrete. Traditionally, the design steel percentage has been based on the thermal characteristics of the concrete at a mature age, although it is the bond behavior of the coarse aggregate controlling the cracking behavior at an early age. However, the thermal effect of the coarse aggregate has a significant effect at later ages upon the width of the transverse crack.

The probabilities of occurrence of different (k) crack spacing can be computed based on design average crack spacing using the following:

$$P_k = Prob(L_U \geq L_k \geq L_L)$$

$$= 100\left[e^{-\left(\frac{L_U - v}{\alpha}\right)^{\beta}} - e^{-\left(\frac{L_L - v}{\alpha}\right)^{\beta}} \right]$$

where

P_k = Probability of occurrence of k^{th} crack spacing

L_U = Upper limit of the cracking interval, inch

L_L = Lower limit of the cracking interval, inch

L_k = k^{th} crack spacing, 1, 2, 3, 4, 5, 6, 7, 8, 9 feet

v = Minimum crack spacing (user input 3 to 4 feet) (or if using crack control, one half of sawcut interval)

L_{max} = $v + \alpha\,(10)^{1/\beta}$; maximum crack spacing

$L_{L\,k}$ = $L_{U\,k} \quad \Delta L$

ΔL = $\dfrac{\alpha(10)^{1/\beta}}{10}$; this divides the difference between the max and min crack spacing into 10 intervals

$$\alpha = \frac{\bar{L} - v}{\Gamma\left(1 + \dfrac{1}{\beta}\right)}$$

$$\Gamma\left(1 + \frac{1}{\beta}\right) = \frac{1}{\beta} e^{Ln\left\{\Gamma\left(\frac{1}{\beta}\right)\right\}}$$

$$Ln\left\{\Gamma\left(\frac{1}{\beta}\right)\right\} = 25.703\left(\frac{1}{\beta}\right)^4 - 61.247\left(\frac{1}{\beta}\right)^3 + 53.007\left(\frac{1}{\beta}\right)^2 - 21.346\left(\frac{1}{\beta}\right) + 4.0845$$

$$\frac{1}{\beta} = 3.0626 + 28.024X \quad 66.374X^2 + 64.653X^3 \quad 23.198X^4$$

$$X = \frac{(\bar{L} - v)^2}{\sigma_{CS}{}^2 + (\bar{L} - v)^2}$$

σ_{CS} = Standard deviation of crack spacing = COV[L]• $\bar{L}$

= $\sqrt{\sum\left(\dfrac{\partial\bar{L}}{\partial X_i}\right)^2 Var\{X_i\} + \sum_{j \neq k}\left(\dfrac{\partial\bar{L}}{\partial X_j}\sigma_j\right)\left(\dfrac{\partial\bar{L}}{\partial X_k}\sigma_k\right)\rho_{jk}}$ (if allowing cracking to occur randomly)

where $X_i = f_t$, C(from $\sigma_{env\,ki}$ formula), σ_o (from $\sigma_{env\,ki}$ formula), h_{PCC}, ζ, f, U_m, and c_1 (see Tables A-3 and A-4 below for values of $\dfrac{\partial\bar{L}}{\partial X_i}$ and Var $\{X_i\}$)

ρ_{jk} = Correlation coefficient (see correlation matrix Table A-5)

Table A-3. Table of Derivatives.

$\frac{\partial \overline{L}}{\partial f_t}$	A = $\left(\frac{f}{2}+\frac{U_m p}{c_1 d_b}\right)^{-1}$	$\frac{\partial \overline{L}}{\partial c}$	$-\sigma_o\left(1-\frac{2\zeta}{h_{PCC}}\right)A = \sigma_o BA$ B=
$\frac{\partial \overline{L}}{\partial \sigma_{ot}}$	= cBA	$\frac{\partial \overline{L}}{\partial h_{PCC}}$	$\left(-\frac{\partial c}{\partial h_{PCC}}\sigma_o(B)-c\sigma_o\left(\frac{4\zeta}{h^2{}_{PCC}}\right)\right)A$
$\frac{\partial c}{\partial h_{PCC}}$	$-\frac{3\overline{L}}{4\sqrt{8}h_{PCC}\ell}\{\Re\}$ (see note below the table about $\Re$ computation)	$\frac{\partial \overline{L}}{\partial \zeta}$	$c\sigma_o\left(\frac{2}{h_{PCC}}\right)A$
$\frac{\partial \overline{L}}{\partial f}$	$(f_t-c\sigma_o B)\frac{A^2}{2}$	$\frac{\partial \overline{L}}{\partial U_m}$	$(f_t-c\sigma_o B)A^2\frac{p}{c_1 d_b}$
$\frac{\partial \overline{L}}{\partial c_1}$	$(f_t-c\sigma_o B)A^2\frac{U_m p}{c^2{}_1 d_b}$		

NOTE:

$$\Re = \{2\sin\lambda\cosh\lambda\ (\tan\lambda + \tanh\lambda) - 2\cos\lambda\sin\lambda\ (\tan\lambda + \tanh 2\lambda) - 2\cos\lambda\cosh l \left(\frac{1}{\cos^2\lambda}+\frac{1}{\cosh^2 2\lambda}\right) + \frac{2\cos\lambda\cosh\lambda(\tan\lambda+\tanh 2\lambda)}{\sin 2\lambda+\sinh 2\lambda}(2\cos 2\lambda + 2\cosh 2\lambda)\}$$

$$\lambda = \frac{L}{\sqrt{8}\ell}$$

Table A-4. Table of Coefficients of Variation.

Var $\{f_t\}$	$0.15^2\,\overline{f_t}$	Var $\{C\}$	$0.25^2\,\overline{C}$
Var $\{\sigma_o\}$	$0.10^2\,\overline{\sigma_o}$	Var $\{h_{PCC}\}$	$0.20^2\,\overline{h_{PCC}}$
Var $\{\zeta\}$	$0.30^2\,\overline{\zeta}$	Var $\{f\}$	$0.25^2\,\overline{f}$
Var $\{U_m\}$	$0.40^2\,\overline{U_m}$	Var $\{c_1\}$	$0.05^2\,\overline{c_1}$

$\overline{L}$ = Mean crack spacing (inch, design average crack spacing) computed from Part 2, Step 9.

Table A-5. Correlation for Cracking Parameters.

	f_t	C	σ_0	H	ς	f	U_m	C_1
f_t	-							
C	0.5	-						
σ_0	0.5	0.5	-					
H	0	1.0	0	-				
ς	0	0	0	0	-			
f	0	0	0	0	0	-		
U_m	1.0	0.5	0.5	0	0	0	-	
C_1	0	0	0	0	0	0	1.0	-

The number of intervals (CI_k) at a given k^{th} interval in 1 mile of pavement can be calculated as:

$$CI_k = (5280/\bar{L})^* P_k$$

$$= \frac{5280}{\bar{L}} * \left[\Pr ob(L_U \geq L_k \geq L_L)\right]$$

where

CI_k = The number of possible k^{th} cracking intervals in a mile (5280 feet) of pavement

P_k = Probability of occurrence of k^{th} crack spacing as noted above

APPENDIX B

CRACK LOAD TRANSFER DETERIORATION

APPENDIX B: CRACK LOAD TRANSFER DETERIORATION

B.1 CRACK LTE DETERIORATION

Field observations of load transfer efficiency (LTE) and crack width have been used to calibrate the relationship between crack width and the loss of LTE over time and traffic. The expression for Δs constitutes the wear-out function that allows for the consideration of the deterioration of the aggregate interlock. Setting the LTE equation equal to zero shear loss yields a threshold value of the dimensionless term $\omega/h = 3.68$, below which no loss in shear capacity occurs. Examination of crack width data obtained from CRC pavement field measurements (Figure B-1) suggests that a LTE of approximately 91 percent is associated with $\omega/h = 3.1$, which has been shifted to the 3.68 value based on analysis of LTPP GPS 5 data, previously noted. In terms of the data trends in Figure B-1, perhaps it can be suggested that with load transfer efficiency above the 90 to 92 percent range, minimal loss of shear capacity is expected to occur. The crack widths shown in Figure B-1 were back calculated from equations for the given slab thickness and measured load transfer efficiency. The equations also provide an estimate of the loss of shear capacity as a function of slab characteristics and load repetition. The deteriorated level of shear capacity can be determined using a similar equation:

$$s_{new} = s_{old} - \Delta s$$

where Δs is based on the LTE equation and s_{old} is the shear capacity prior to the loading increment, and s_{new} is the resultant capacity due the loading increment. The Δs may also be due to a change in crack/joint opening.

The following example further compares the results of the predicted LTE deterioration process with the field data obtained for LTPP GPS-5 section 175849. The field LTE data were obtained from the FWD measurements taken on two separate surveys (November 1989 and July 1994). Table B-1 summarizes characteristics of this LTPP section. As shown in Figure B-2, predicted and measured mean LTE values are very close. Measured values were taken at 18 and 23 years after construction.

Crack shear capacity and associated LTE values are very sensitive to crack width over thickness ratio. The higher the ratio, the lower initial shear capacity and faster the rate of LTE deterioration. For a given PCC thickness, wider cracks would deteriorate first. Wider cracks are usually associated with pairs of slabs with large mean crack spacing. The situation is most critical when a narrow loaded slab segment is located next to a wide slab segment.

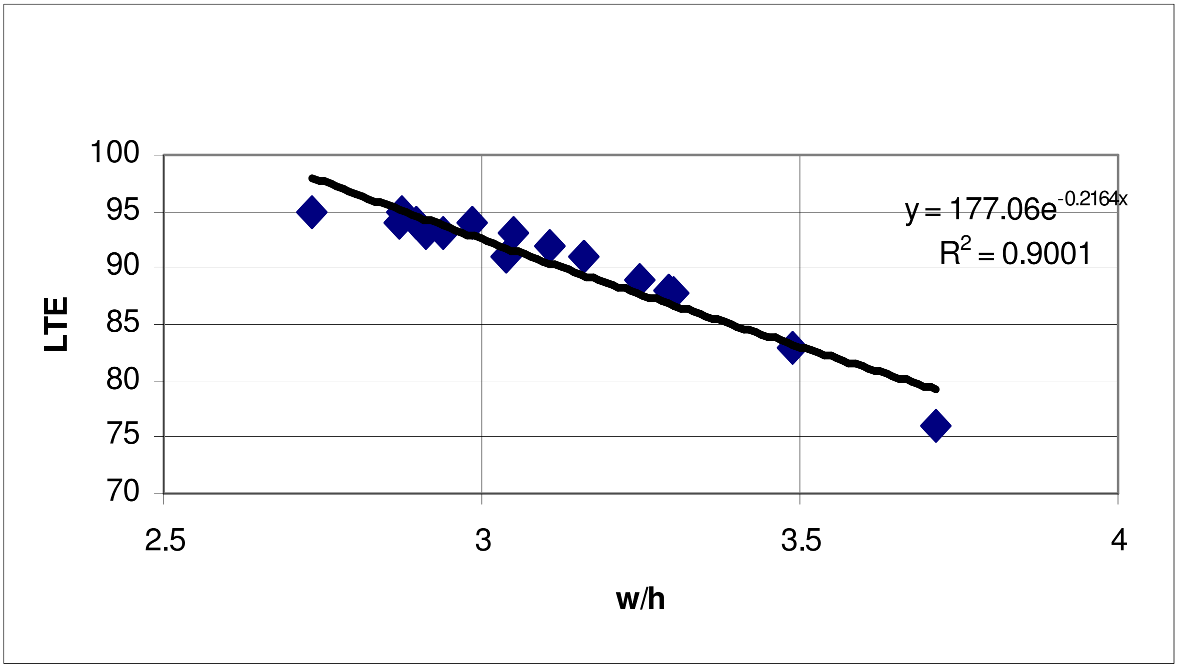

Figure B-1. Trend in Load Transfer Data with Effective Crack Width Data.

Table B-1. Characteristics of the LTPP GPS-5 Section 175849 (Gharaibeh 1999).

Section Characteristics	Values
Estimated Concrete Elastic Modulus at 28 day	20,670 MPa (3,000,000 psi)
Slab Thickness	183 mm (7.2 in)
Depth to Steel	76 mm (3 in)
Percent of Longitudinal Reinforcement	0.7%
Steel Bar Diameter	16 mm (0.63 in)
Base Material Description	ATB
Shoulder Type	Asphalt Concrete
Measured Mean Crack Spacing	0.75 m (30 in)
Cumulative Axle Loading	13,000,000 ESAL
Annual Truck Volume Growth	2%

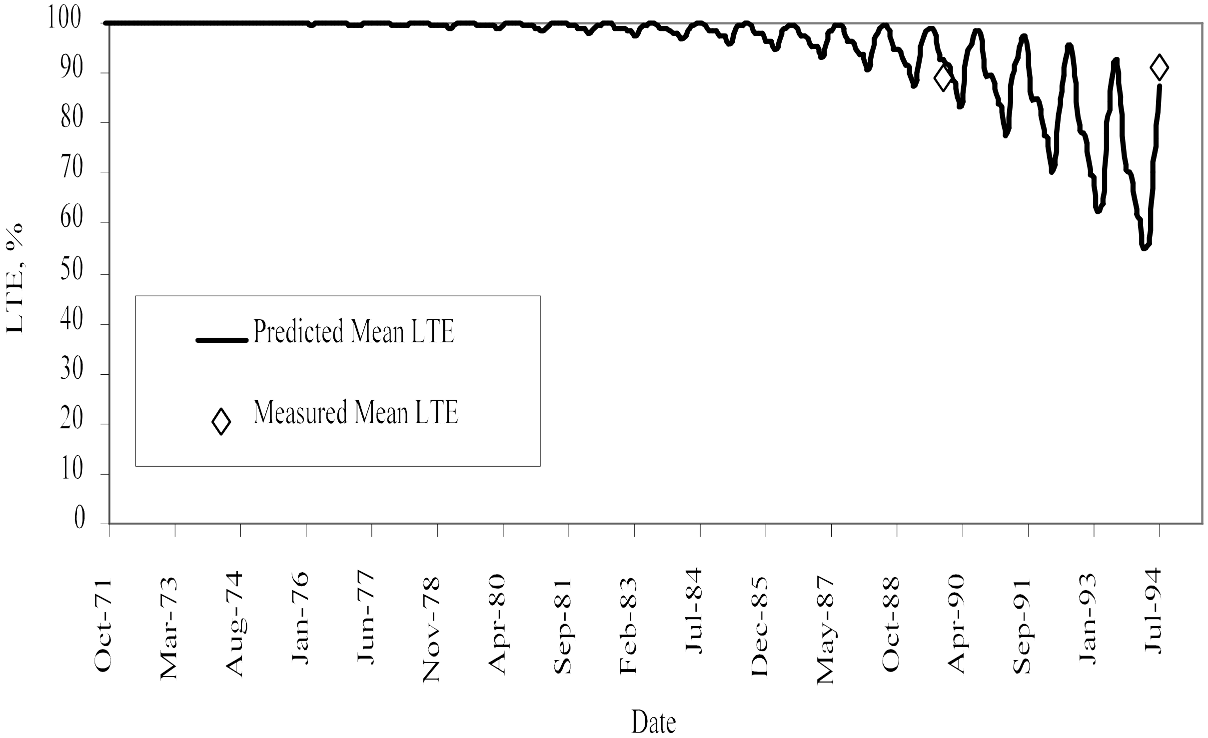

Figure B-2. Comparison of Predicted and Measured LTE for LTPP GPS-5 Section 175849 in Illinois (Gharaibeh 1999).

APPENDIX C

DRY-COLD, AC-THIN RESULTS

Table C-1. Dry-Cold, AC-Thin, Highly Significant Variables - Longitudinal Cracking.

Variable	Category	Long-Rank
Base Construction − 2 month	01-General	0.4
All Tire Press +30 psi	03-Traffic-General-Axle	0.3
All Tire Press −30 psi	03-Traffic-General-Axle	0.2
Dual Tire Press +30 psi	03-Traffic-General-Axle	0.3
Dual Tire Press −30 psi	03-Traffic-General-Axle	0.2
Elevation −1500'	04-Climate	0.5
Elevation +1500'	04-Climate	0.3
Longitude −1	04-Climate	0.4
AC Layer +0.5"	07-AC	0.2
AC Layer +1.5"	07-AC	0.1
AC Layer −0.5"	07-AC	0.1
AC Air Voids +3.8%	07-AC-General	0.1
AC Air Voids −1.7%	07-AC-General	0.3
AC Eff Binder Cont +3%	07-AC-General	0.5
AC Eff Binder Cont −3%	07-AC-General	0.2
CS Low Soil Water Value	08-CS-ICM	0.5
CS Sat Hyd Cond - Def	08-CS-ICM	0.3
CS Uncompacted	08-CS-ICM	0.3
Crushed Stone Layer −1"	08-CS-Str	0.5
CS High Soil Water Value	08-CS-Str	0.0
CS Resilient Modulus×2	08-CS-Str	0.1
CS Resilient Modulus/2	08-CS-Str	0.1
CHLS D60/4	09-CHLS-ICM	0.3
CHLS Def Soil Water Value	09-CHLS-ICM	0.3
CHLS Low Soil Water Value	09-CHLS-ICM	0.2
CHLS P200 +70%	09-CHLS-ICM	0.3
CHLS P200 −10%	09-CHLS-ICM	0.2
CHLS Sat Hyd Cond/3.7	09-CHLS-ICM	0.5
SG PI −10	10-SG-ICM	0.2
SG Uncompacted	10-SG-ICM	0.4
SG Resilient Modulus −5 ksi	10-SG-Str	0.4

Table C-2. Dry-Cold, AC-Thin, Significant Variables - Longitudinal Cracking.

Variable	Category	Long-Rank
Local Road TTC Class 9	02-Site	0.8
AADT −18 (20%)	03-Traffic	1.0
AADT +18 (20%)	03-Traffic	1.0
Wander 2" LESS	03-Traffic-General	0.9
Wander 2" MORE	03-Traffic-General	1.8
Longitude +1	04-Climate	1.7
Water Table Depth at 1'	04-Climate	2.0
AC Heat Capacity +0.08	07-AC-General	1.8
AC Heat Capacity +0.17	07-AC-General	1.4
AC Poisson’s Ratio −0.05	07-AC-General	0.8
AC Poisson’s Ratio +0.05	07-AC-General	0.8
AC Thermal Conductivity +0.14	07-AC-General	1.5
AC Dynamic Mod/1.5	07-AC-Mix	0.6
AC Dynamic Mod×1.5	07-AC-Mix	0.6
CS D60×1.175	08-CS-ICM	2.4
CS Def Soil Water Value	08-CS-ICM	2.4
CS P200 −3%	08-CS-ICM	2.1
CS Sat Hyd Cond×5/12	08-CS-ICM	2.4
CS Unit Wt −6 pcf	08-CS-ICM	0.7
CS Poisson’s Ratio −0.05	08-CS-Str	1.8
CS Poisson’s Ratio +0.05	08-CS-Str	1.8
CHLS Grav Water Con −3.2%	09-CHLS-ICM	2.4
CHLS High Soil Water Value	09-CHLS-ICM	1.4
CHLS PI −2	09-CHLS-ICM	0.6
CHLS Uncompacted	09-CHLS-ICM	2.4
CHLS Unit Wt −12 pcf	09-CHLS-ICM	2.4
CH Lime Stab Layer +2"	09-CHLS-Str	1.3
CH Lime Stab Layer −2"	09-CHLS-Str	1.1
CHLS Resilient Mod×0.7	09-CHLS-Str	1.2
CHLS Resilient Mod×1.3	09-CHLS-Str	1.7
SG High Soil Water Value	10-SG-ICM	2.3
SG Sat Hyd Cond	10-SG-ICM	2.3
SG Sat Hyd Cond/10	10-SG-ICM	2.0
SG Unit Wt −11 psi	10-SG-ICM	0.6
SG Resilient Modulus +5 ksi	10-SG-Str	0.6
SG Thickness +25"	10-SG-Str	1.4

Table C-3. Dry-Cold, AC-Thin, Highly Significant Variables - Alligator Cracking.

Description	Category	Allig-Rank
Base Construction −2 month	01-General	0.3
All Tire Press +30 psi	03-Traffic-General-Axle	0.3
All Tire Press −30 psi	03-Traffic-General-Axle	0.4
Dual Tire Press +30 psi	03-Traffic-General-Axle	0.3
Dual Tire Press −30 psi	03-Traffic-General-Axle	0.4
Elevation −1500'	04-Climate	0.4
Elevation +1500'	04-Climate	0.4
Longitude −1	04-Climate	0.3
AC Layer +1.5"	07-AC	0.3
AC Layer −0.5"	07-AC	0.3
AC Air Voids +3.8%	07-AC-General	0.1
AC Air Voids −1.7%	07-AC-General	0.4
AC Eff Binder Cont +3%	07-AC-General	0.5
AC Eff Binder Cont −3%	07-AC-General	0.2
CS Sat Hyd Cond - Def	08-CS-ICM	0.3
CS Uncompacted	08-CS-ICM	0.5
Crushed Stone Layer −1"	08-CS-Str	0.3
CS High Soil Water Value	08-CS-Str	0.1
CS Resilient Modulus×2	08-CS-Str	0.4
CS Resilient Modulus/2	08-CS-Str	0.1
CHLS D60/4	09-CHLS-ICM	0.3
CHLS Def Soil Water Value	09-CHLS-ICM	0.3
CHLS High Soil Water Value	09-CHLS-ICM	0.3
CHLS Low Soil Water Value	09-CHLS-ICM	0.3
CHLS P200 +70%	09-CHLS-ICM	0.3
CHLS P200 −10%	09-CHLS-ICM	0.3
CHLS Sat Hyd Cond/3.7	09-CHLS-ICM	0.5
SG PI −10	10-SG-ICM	0.5
SG Uncompacted	10-SG-ICM	0.3
SG Unit Wt −11 psi	10-SG-ICM	0.5

Table C-4. Dry-Cold, AC-Thin, Significant Variables - Alligator Cracking.

Description	Category	Allig-Rank
Local Road TTC Class 9	02-Site	0.7
Minor Arterial TTC Class 4	02-Site	1.4
AADT −18 (20%)	03-Traffic	1.0
AADT +18 (20%)	03-Traffic	1.0
Wander 2" LESS	03-Traffic-General	1.4
Wander 2" MORE	03-Traffic-General	1.7
Latitude +0.6	04-Climate	1.7
Longitude +1	04-Climate	2.4
Water Table Depth at 1'	04-Climate	1.7
AC Layer +0.5"	07-AC	2.2
Visc Graded Level 1 Def	07-AC-Binder-AC-1	2.1
AC Heat Capacity +0.08	07-AC-General	1.8
AC Heat Capacity +0.17	07-AC-General	1.4
AC Thermal Conductivity +0.14	07-AC-General	1.7
AC Dynamic Mod/1.5	07-AC-Mix	1.2
AC Dynamic Mod×1.5	07-AC-Mix	2.2
CS Def Soil Water Value	08-CS-ICM	2.1
CS Low Soil Water Value	08-CS-ICM	0.9
CS P200 −3%	08-CS-ICM	1.8
CS Unit Wt −6 pcf	08-CS-ICM	1.0
CS Poisson's Ratio −0.05	08-CS-Str	2.4
CS Poisson's Ratio +0.05	08-CS-Str	2.3
CHLS PI −2	09-CHLS-ICM	1.1
CHLS Resilient Mod×0.7	09-CHLS-Str	1.5
CHLS Resilient Mod×1.3	09-CHLS-Str	2.5

Table C-5. Dry-Cold, AC-Thin, Highly Significant Variables - AC Rutting

Description	Category	ACRut-Rank
All Tire Press +30 psi	03-Traffic-General-Axle	0.3
All Tire Press −30 psi	03-Traffic-General-Axle	0.2
Dual Tire Press +30 psi	03-Traffic-General-Axle	0.3
Dual Tire Press −30 psi	03-Traffic-General-Axle	0.2
Elevation +1500'	04-Climate	0.4
AC Layer +0.5"	07-AC	0.2
AC Layer +1.5"	07-AC	0.1
AC Layer −0.5"	07-AC	0.1
AC PG Grade 58-34	07-AC-Binder-SP-3	0.5
AC PG Grade 76-22	07-AC-Binder-SP-3	0.4
AC Air Voids +3.8%	07-AC-General	0.4
AC Dynamic Mod/1.5	07-AC-Mix	0.3
AC Dynamic Mod×1.5	07-AC-Mix	0.5
CS High Soil Water Value	08-CS-Str	0.2
CS Resilient Modulus×2	08-CS-Str	0.4
CS Resilient Modulus/2	08-CS-Str	0.3

Table C-6. Dry-Cold, AC-Thin, Significant Variables - AC Rut Rank.

Description	Category	ACRut-Rank
Base Construction −2 month	01-General	0.8
Local Road TTC Class 9	02-Site	0.8
AADT −18 (20%)	03-Traffic	0.9
AADT +18 (20%)	03-Traffic	1.1
Wander 2" LESS	03-Traffic-General	1.6
Latitude +0.6	04-Climate	1.6
Longitude +1	04-Climate	2.1
Longitude −1	04-Climate	1.6
Surface Shortwave Absorp −0.05	06-Drain	2.1
Surface Shortwave Absorp +0.05	06-Drain	1.6
Visc Graded Level 1 Def	07-AC-Binder-AC-1	0.6
AC Visc Grade 20	07-AC-Binder-AC-3	1.3
AC Visc Grade 5	07-AC-Binder-AC-3	0.7
AC G* Delta×3	07-AC-Binder-SP-1	1.1
AC G* Delta/3	07-AC-Binder-SP-1	1.3
AC Air Voids −1.7%	07-AC-General	2.1
AC Eff Binder Cont +3%	07-AC-General	1.3
AC Eff Binder Cont −3%	07-AC-General	1.1
AC Heat Capacity +0.08	07-AC-General	1.6
AC Heat Capacity +0.17	07-AC-General	1.1
AC Poisson’s Ratio −0.05	07-AC-General	0.7
AC Poisson’s Ratio +0.05	07-AC-General	0.7
AC % Pass #200 −2.5%	07-AC-Mix	1.1
AC % Retained #4" +10%	07-AC-Mix	1.3
AC % Retained #4" −10%	07-AC-Mix	1.6
AC All Gradations Low Side	07-AC-Mix	1.6
CS Low Soil Water Value	08-CS-ICM	1.6
CS Sat Hyd Cond - Def	08-CS-ICM	0.7
CS Uncompacted	08-CS-ICM	2.1
Crushed Stone Layer −1"	08-CS-Str	1.6
CS Poisson's Ratio −0.05	08-CS-Str	1.6
CS Poisson's Ratio +0.05	08-CS-Str	1.3
CHLS D60/4	09-CHLS-ICM	0.7
CHLS Def Soil Water Value	09-CHLS-ICM	0.6
CHLS High Soil Water Value	09-CHLS-ICM	1.6
CHLS Low Soil Water Value	09-CHLS-ICM	0.6
CHLS P200 +70%	09-CHLS-ICM	0.7
CHLS P200 −10%	09-CHLS-ICM	0.6
CHLS PI −2	09-CHLS-ICM	1.3
CHLS Sat Hyd Cond/3.7	09-CHLS-ICM	1.1

Table C-6. Dry-Cold, AC-Thin, Significant Variables - AC Rut Rank (Continued).

SG PI −10	10-SG-ICM	0.6
SG Uncompacted	10-SG-ICM	0.8
SG Unit Wt −11 psi	10-SG-ICM	1.3
SG Resilient Modulus +5 ksi	10-SG-Str	2.1
SG Resilient Modulus −5 ksi	10-SG-Str	1.3
SG Thickness +25"	10-SG-Str	1.1

Table C-7. Dry-Cold, AC-Thin, Highly Significant Variables - Total Rutting Rank.

Description	Category	TotRut-Rank
Local Road TTC Class 9	02-Site	0.4
ALL Tire Press −30PSI	03-Traffic-General-Axle	0.4
Dual Tire Press −30PSI	03-Traffic-General-Axle	0.4
Water Table Depth at 1'	04-Climate	0.3
CS High Soil Water Value	08-CS-Str	0.3
CS Resilient Modulus×2	08-CS-Str	0.5
CS Resilient Modulus/2	08-CS-Str	0.4
SG PI −10	10-SG-ICM	0.4
SG Resilient Modulus −5 ksi	10-SG-Str	0.5
SG Thickness + 25"	10-SG-Str	0.5

Table C-8. Dry-Cold, AC-Thin, Significant Variables - Total Rutting Rank.

Description	Category	TotRut-Rank
Base Construction - 2 month	01-General	0.9
Minor Arterial TTC Class 4	02-Site	0.7
AADT −18 (20%)	03-Traffic	0.9
AADT +18 (20%)	03-Traffic	1.1
Wander 2" Less	03-Traffic-General	1.8
All Tire Press +30 psi	03-Traffic-General-Axle	0.7
Dual Tire Press +30 psi	03-Traffic-General-Axle	0.7
Elevation +1500'	04-Climate	0.6
Longitude −1	04-Climate	1.2
Water Table Depth at 100'	04-Climate	1.7
Water Table Depth at 50'	04-Climate	1.7
AC Layer +0.5"	07-AC	1.5
AC Layer −0.5"	07-AC	2.3
Visc Graded Level 1 Def	07-AC-Binder-AC-1	1.1
AC Visc Grade 20	07-AC-Binder-AC-3	2.3
AC Visc Grade 5	07-AC-Binder-AC-3	1.7
AC G*Delta×3	07-AC-Binder-SP-1	1.8
AC G*Delta/3	07-AC-Binder-SP-1	2.3
AC PG Grade 58-34	07-AC-Binder-SP-3	1.1
AC PG Grade 76-22	07-AC-Binder-SP-3	0.8
AC Air Voids +3.8%	07-AC-General	0.8
AC Eff Binder Cont −3%	07-AC-General	1.8
AC Heat Capacity +0.17	07-AC-General	1.8
AC Poisson’s Ratio −0.05	07-AC-General	1.8
AC Poisson’s Ratio +0.05	07-AC-General	1.7
AC % Pass #200 −2.5%	07-AC-Mix	2.3
AC % Retained #4" +10%	07-AC-Mix	2.3
AC % Retained #4" −10%	07-AC-Mix	2.3
AC Dynamic Mod/1.5	07-AC-Mix	0.6
AC Dynamic Mod ×1.5	07-AC-Mix	0.8
CS Sat Hyd Cond - Def	08-CS-ICM	0.8
Crushed Stone Layer +1"	08-CS-Str	1.2
Crushed Stone Layer −1"	08-CS-Str	0.6
CHLS D60/4	09-CHLS-ICM	0.8
CHLS Def Soil Water Value	09-CHLS-ICM	1.0
CHLS High Soil Water Value	09-CHLS-ICM	1.2
CHLS Low Soil Water Value	09-CHLS-ICM	1.0
CHLS P200 + 70%	09-CHLS-ICM	0.8
CHLS P200 - 10%	09-CHLS-ICM	0.9
CHLS Sat Hyd Cond/3.7	09-CHLS-ICM	1.7

Table C-8. Dry-Cold, AC-Thin, Significant Variables - Total Rutting Rank (Continued).

CH LS Poisson's Ratio −0.15	09-CHLS-Str	1.0
CH LS Poisson's Ratio +0.10	09-CHLS-Str	1.7
SG Uncompacted	10-SG-ICM	1.2
SG Unit Wt - 11 pis	10-SG-ICM	2.1
SG Resilient Modulus +5 ksi	10-SG-Str	0.9
SG Thickness −25"	10-SG-Str	0.6

Table C-9. Dry-Cold, AC-Thin, Highly Significant Variables - IRI Rank.

Description	Category	IRI-Rank
Base Construction −2 month	01-General	0.3
Initial IRI +12	02-Analysis	0.2
Initial IRI −13	02-Analysis	0.2
All Tire Press +30 psi	03-Traffic-General-Axle	0.3
All Tire Press −30 psi	03-Traffic-General-Axle	0.3
Dual Tire Press +30 psi	03-Traffic-General-Axle	0.3
Dual Tire Press −30 psi	03-Traffic-General-Axle	0.3
Elevation −1500'	04-Climate	0.2
Latitude +0.6	04-Climate	0.3
Longitude −1	04-Climate	0.2
AC Layer +1.5"	07-AC	0.4
AC Layer −0.5"	07-AC	0.3
AC Air Voids +3.8%	07-AC-General	0.1
AC Air Voids −1.7%	07-AC-General	0.3
AC Eff Binder Cont +3%	07-AC-General	0.5
AC Eff Binder Cont −3%	07-AC-General	0.2
CS Sat Hyd Cond - Def	08-CS-ICM	0.3
CS Uncompacted	08-CS-ICM	0.5
Crushed Stone Layer −1"	08-CS-Str	0.3
CS High Soil Water Value	08-CS-Str	0.0
CS Resilient Modulus×2	08-CS-Str	0.2
CS Resilient Modulus/2	08-CS-Str	0.1
CHLS D60/4	09-CHLS-ICM	0.3
CHLS Def Soil Water Value	09-CHLS-ICM	0.3
CHLS High Soil Water Value	09-CHLS-ICM	0.3
CHLS Low Soil Water Value	09-CHLS-ICM	0.3
CHLS P200 +70%	09-CHLS-ICM	0.2
CHLS P200 −10%	09-CHLS-ICM	0.3
SG PI −10	10-SG-ICM	0.5
SG Uncompacted	10-SG-ICM	0.3
SG Unit Wt −11 psi	10-SG-ICM	0.5

Table C-10. Dry-Cold, AC-Thin, Significant Variables - IRI Rank.

Description	Category	IRI-Rank
Local Road TTC Class 9	02-Site	0.7
Minor Arterial TTC Class 4	02-Site	1.4
AADT −18 (20%)	03-Traffic	1.0
AADT +18 (20%)	03-Traffic	1.0
Wander 2" Less	03-Traffic-General	1.4
Wander 2" More	03-Traffic-General	1.7
Elevation +1500'	04-Climate	2.1
Water Table Depth at 1'	04-Climate	1.6
AC Layer +0.5"	07-AC	0.9
Visc Graded Level 1 Def	07-AC-Binder-AC-1	1.9
AC PG Grade 76-22	07-AC-Binder-SP-3	2.4
AC Heat Capacity +0.08	07-AC-General	1.8
AC Heat Capacity +0.17	07-AC-General	1.5
AC Thermal Conductivity +0.14	07-AC-General	1.6
AC Dynamic Mod/1.5	07-AC-Mix	1.2
AC Dynamic Mod×1.5	07-AC-Mix	2.2
CS Def Soil Water Value	08-CS-ICM	2.1
CS Low Soil Water Value	08-CS-ICM	0.9
CS P200 −3%	08-CS-ICM	1.8
CS Unit Wt −6 pcf	08-CS-ICM	1.0
CS Poisson’s Ratio −0.05	08-CS-Str	2.4
CS Poisson’s Ratio +0.05	08-CS-Str	2.1
CHLS PI −2	09-CHLS-ICM	1.2
CHLS Sat Hyd Cond /3.7	09-CHLS-ICM	0.6
CHLS Resilient Mod×0.7	09-CHLS-Str	1.5
CHLS Resilient Mod×1.3	09-CHLS-Str	2.4

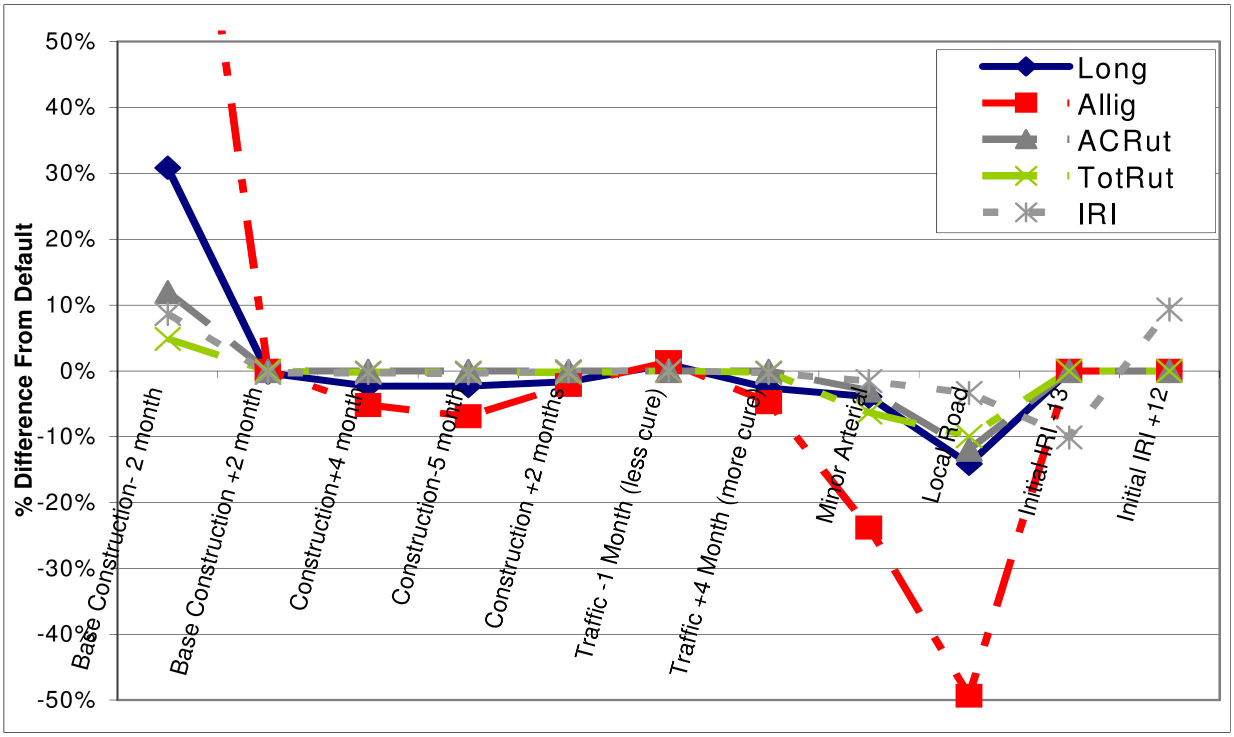

Figure C-1. Dry-Cold, AC-Thin, General Variables.

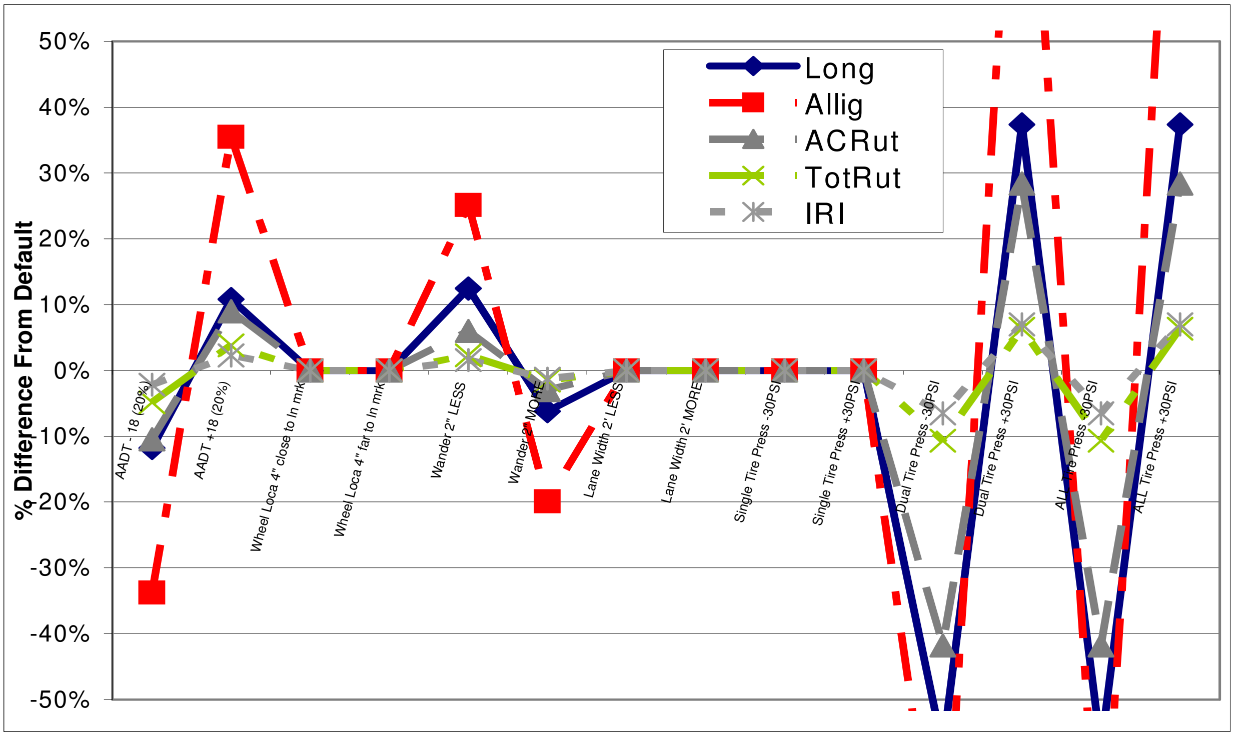

Figure C-2. Dry-Cold, AC-Thin, Traffic Variables.

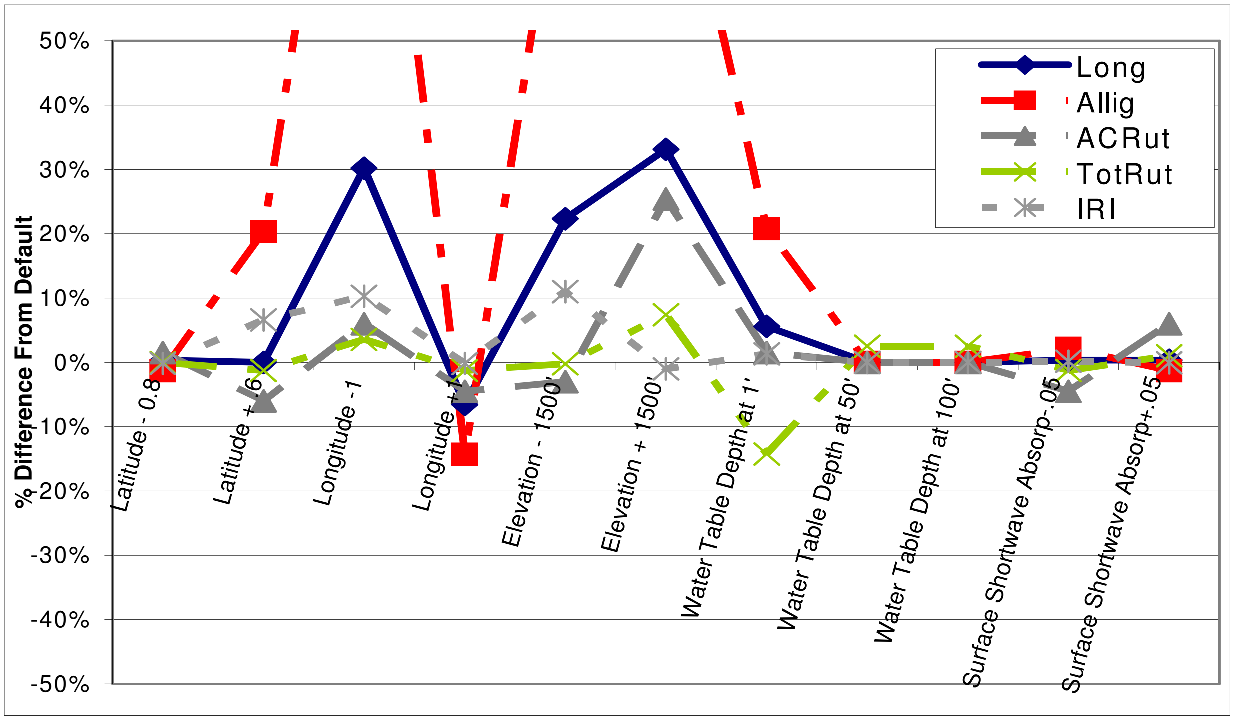

Figure C-3. Dry-Cold, AC-Thin, Climate Variables.

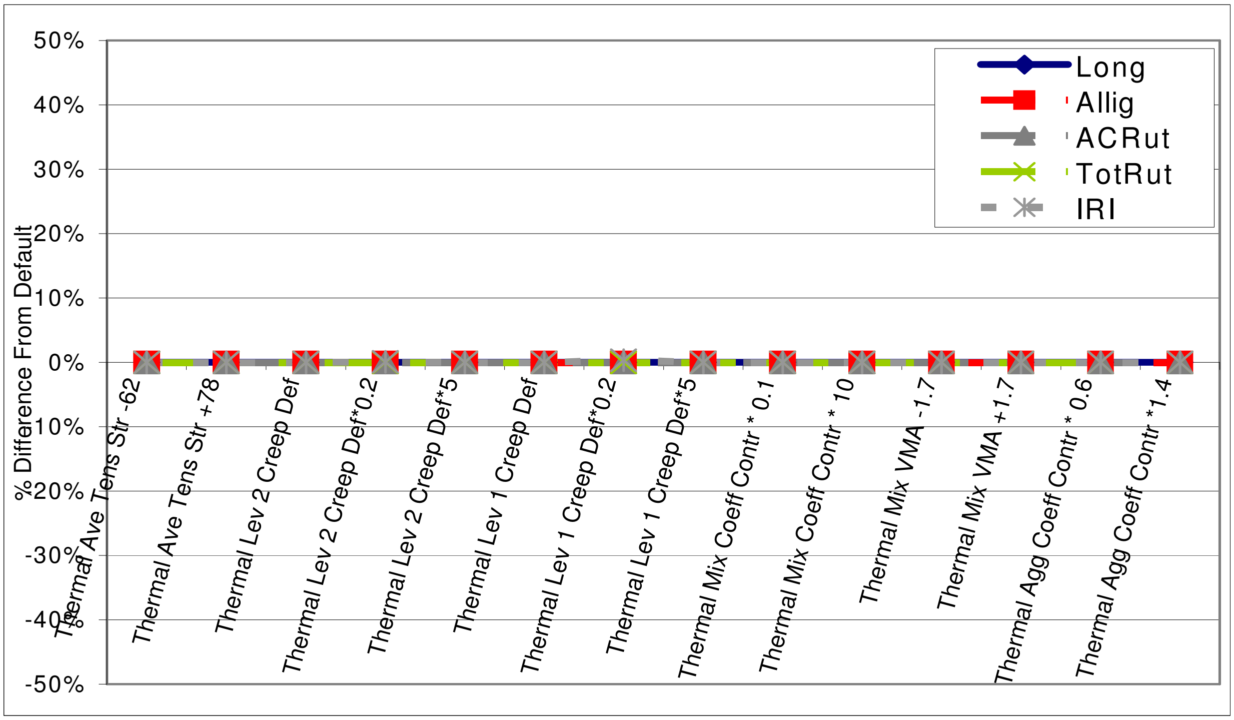

Figure C-4. Dry-Cold, AC-Thin, Thermal Variables.

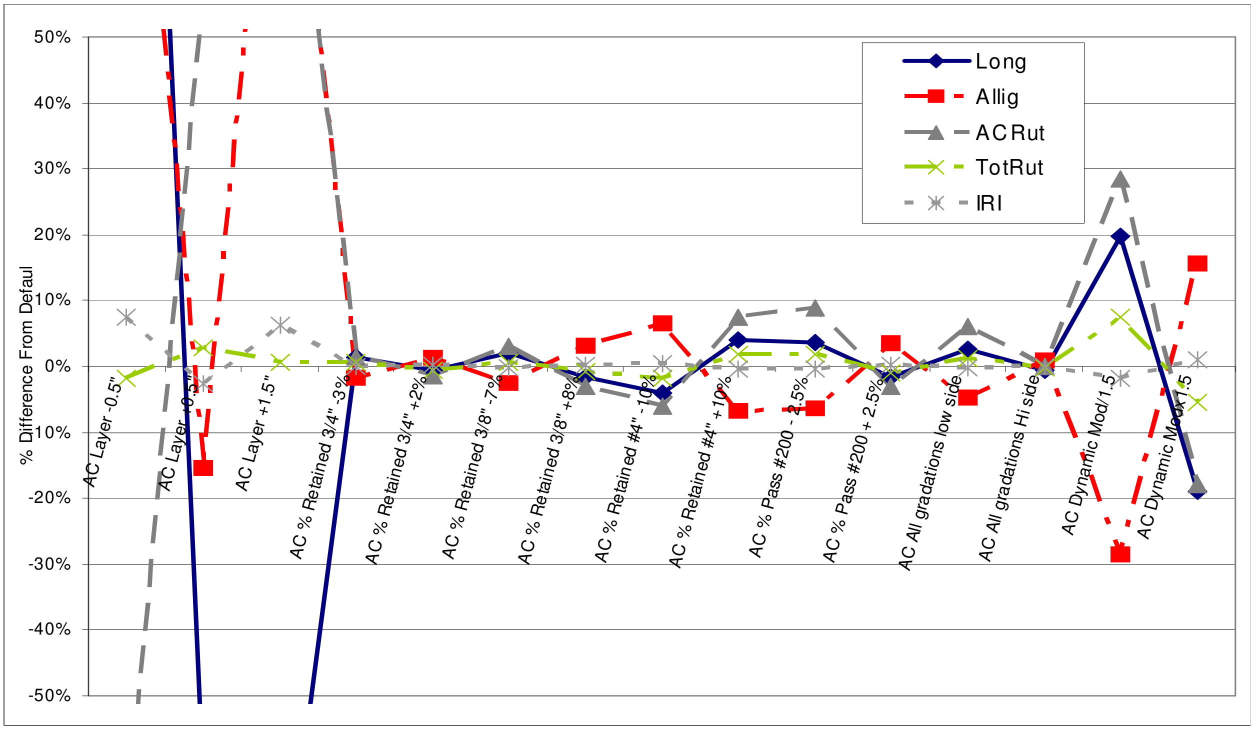

Figure C-5. Dry-Cold, AC-Thin, AC Binder Variables.

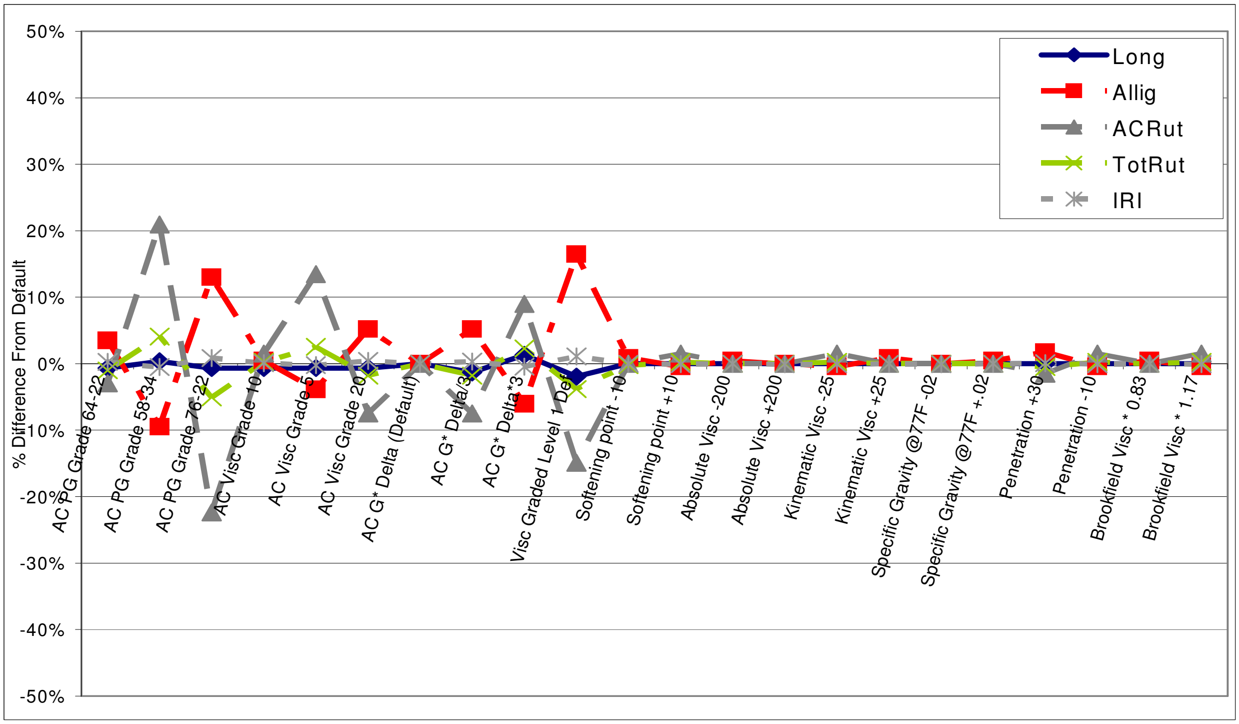

Figure C-6. Dry-Cold, AC-Thin, AC Binder Variables.

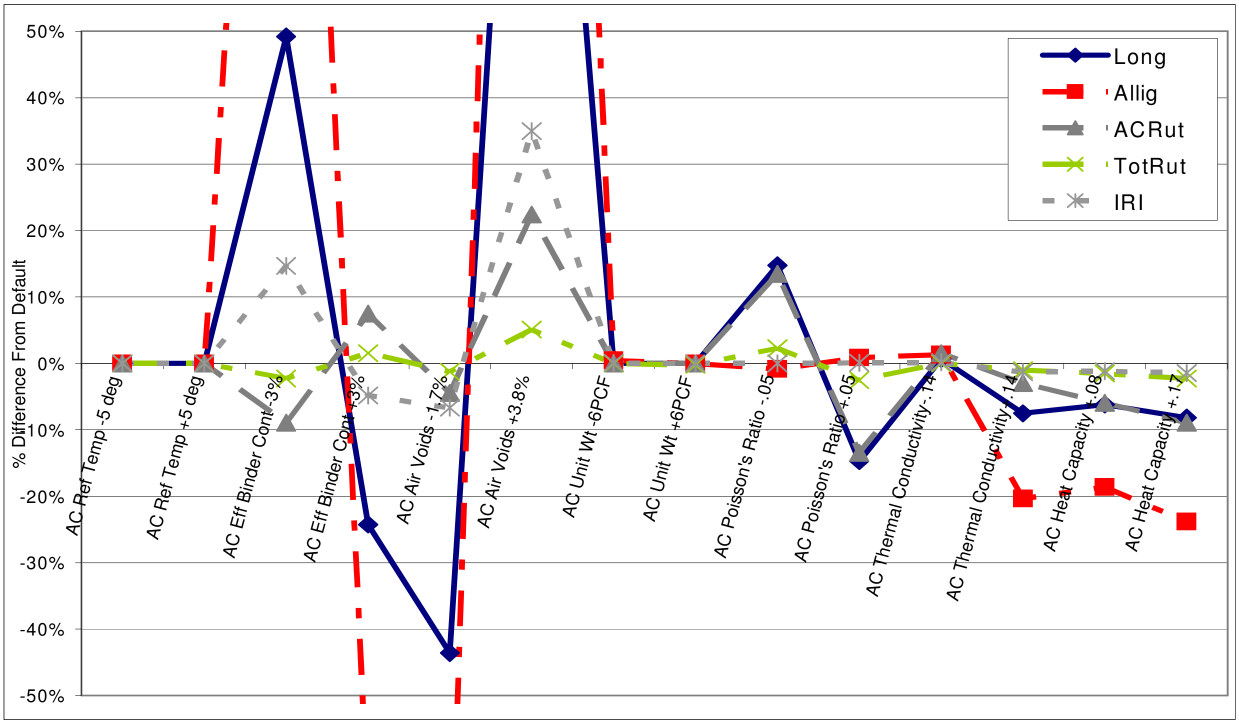

Figure C-7. Dry-Cold, AC-Thin, AC General Variables.

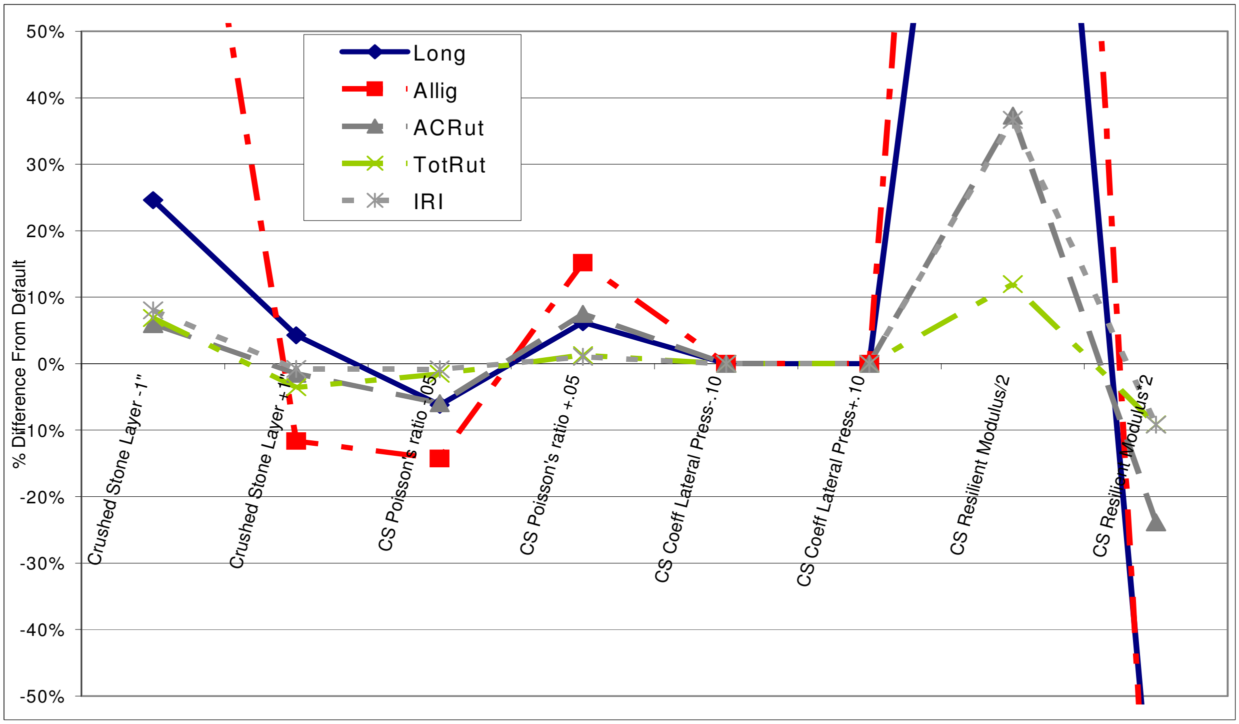

Figure C-8. Dry-Cold, AC-Thin, Crushed Stone Structural Variables.

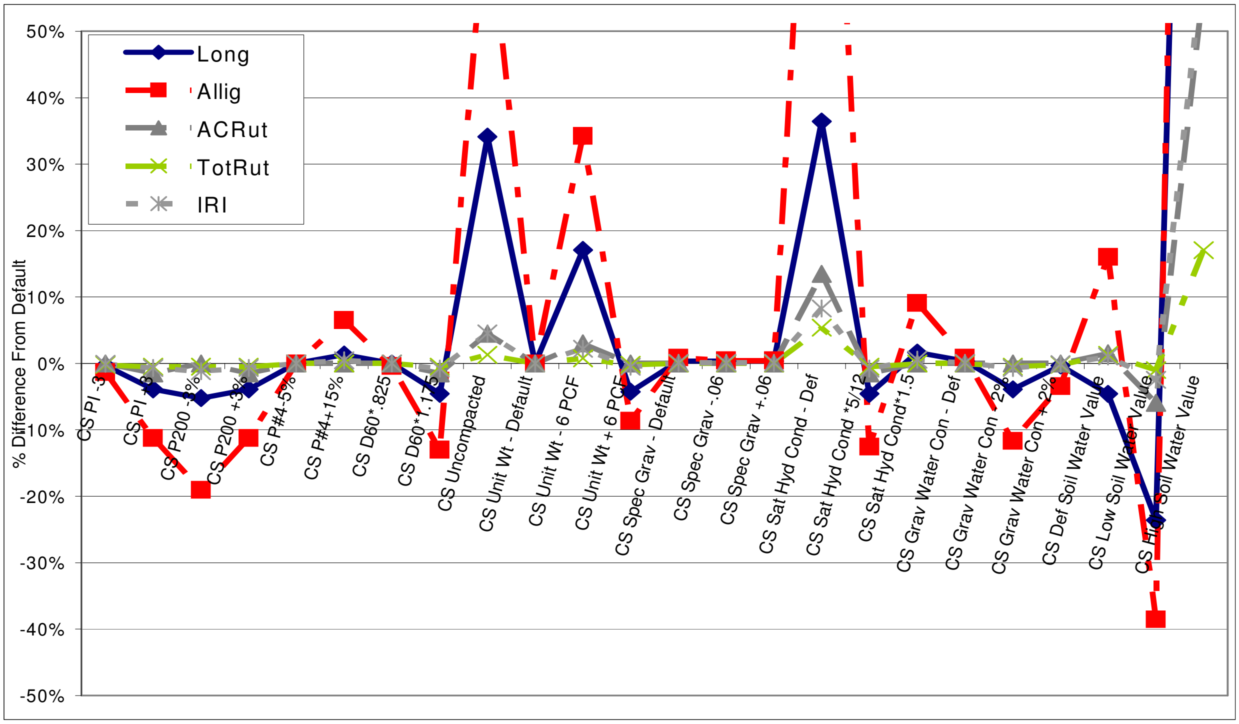

Figure C-9. Dry-Cold, AC-Thin, Crushed Stone Climatic Variables.

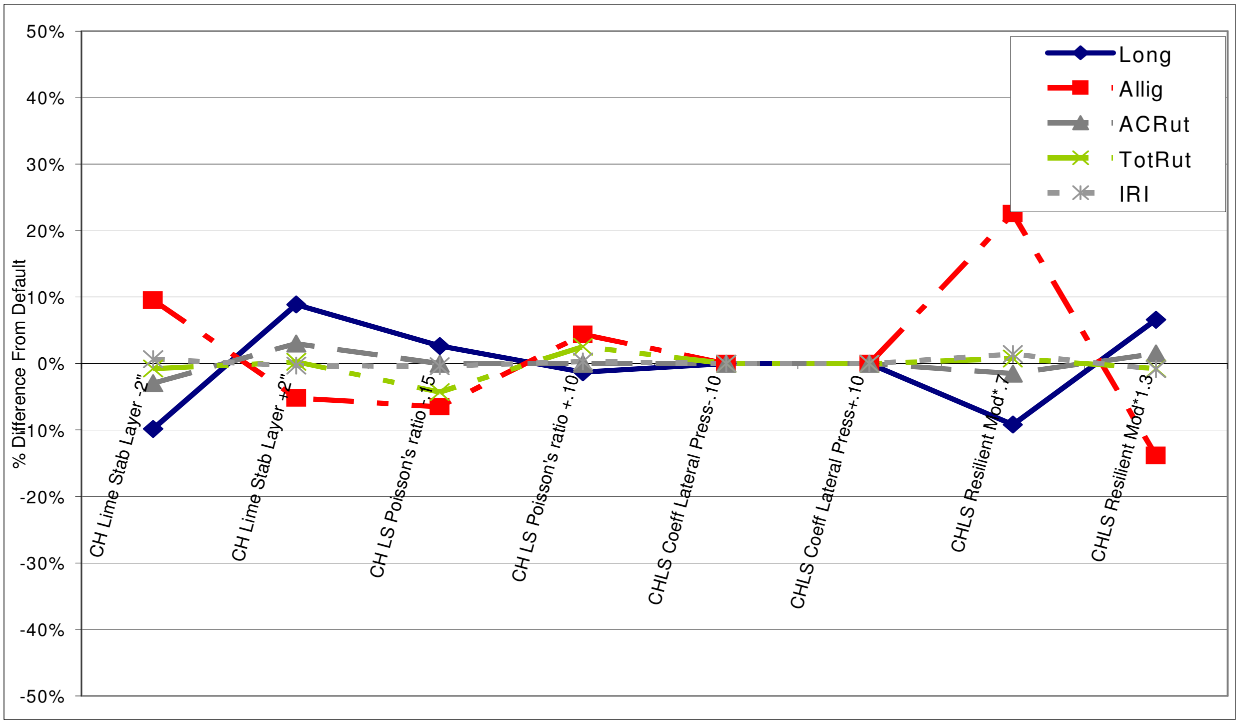

Figure C-10. Dry-Cold, AC-Thin, Lime Treated Structural Variables.

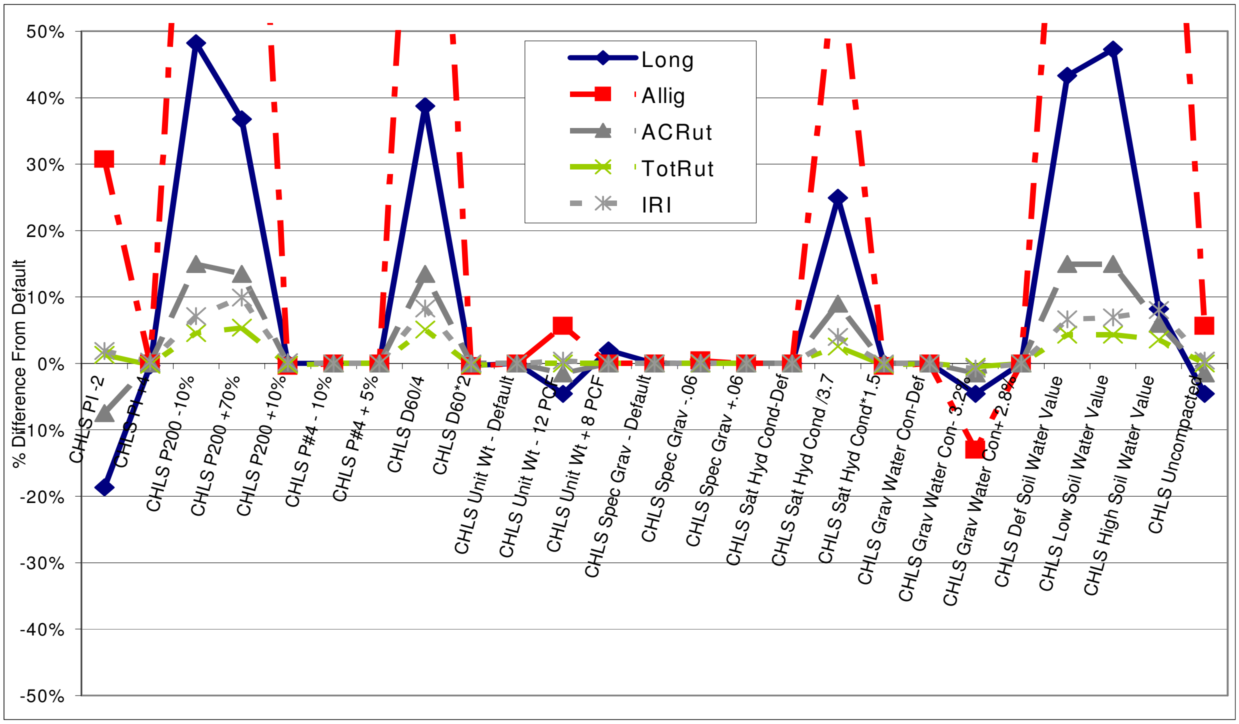

Figure C-11. Dry-Cold, AC-Thin, Lime Treated Climatic Variables.

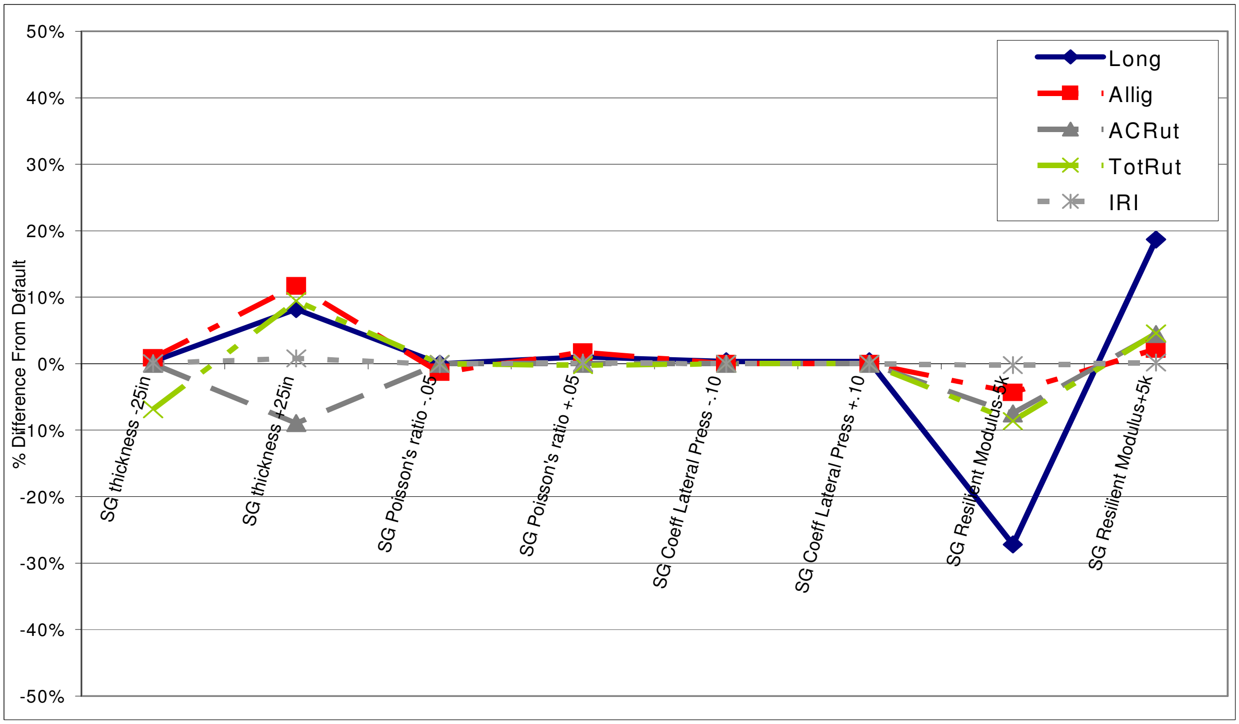

Figure C-12. Dry-Cold, AC-Thin, Subgrade Structural Variables.

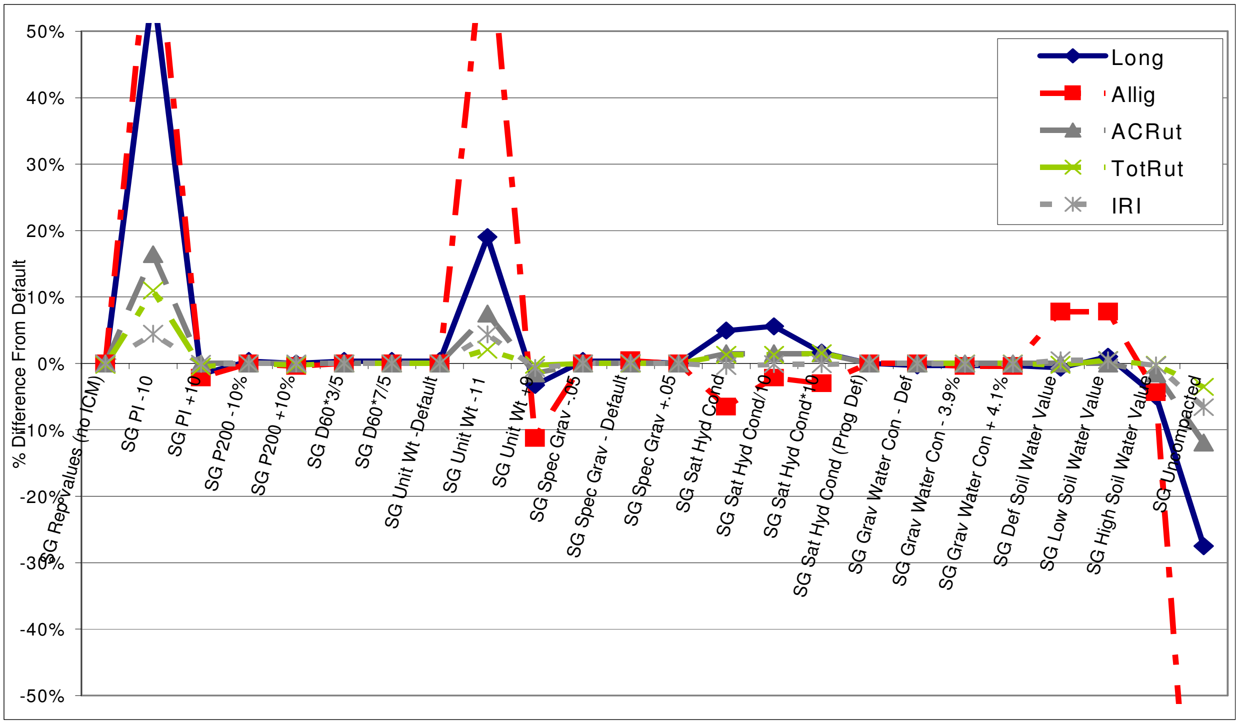

Figure C-13. Dry-Cold, AC-Thin, Subgrade Climatic Variables.

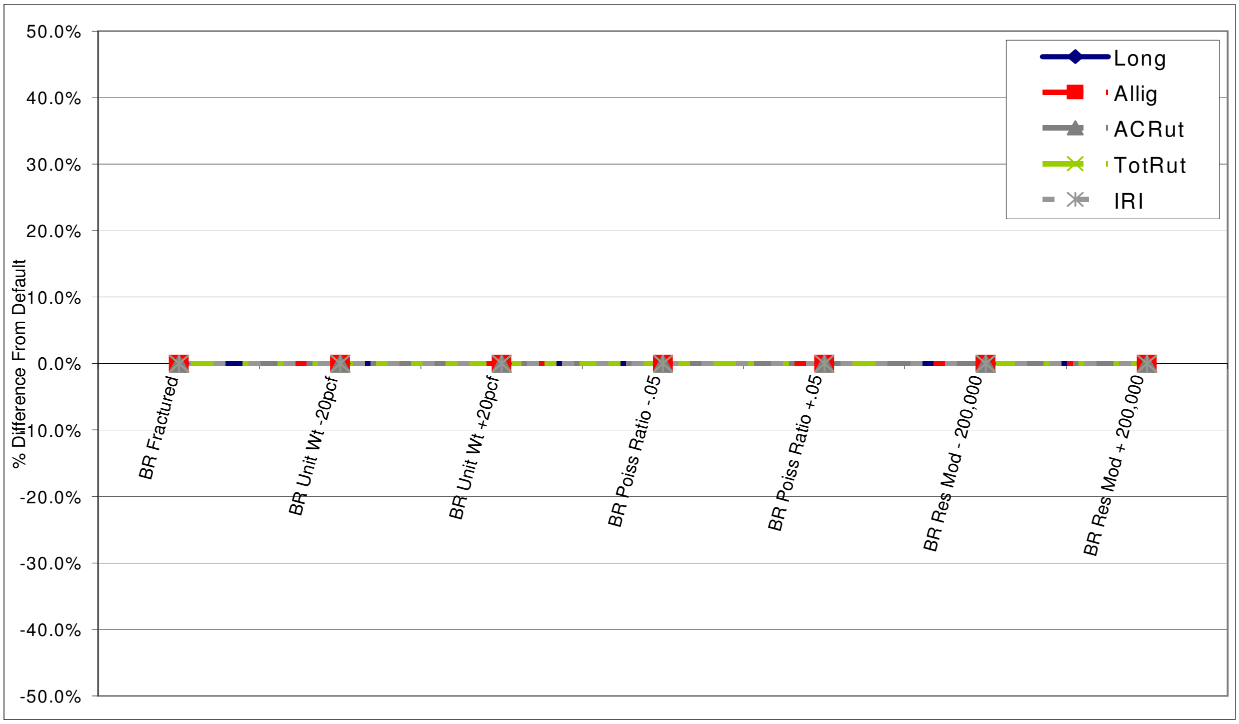

Figure C-14. Dry-Cold, AC-Thin, Bedrock Variables.

Table C-11. Results of Dry-Cold, AC-Thin, General Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
Base Construction −2 month	<	=	=	=	<
Base Construction +2 month	<	<	=	<	<
Construction −2 month	> > >	> > >	> >	> >	> > >
Construction +4 month	<	<	=	<	<
Construction −5 month	<	<	=	<	<
Traffic + 4 month (More Cure)	<	<	=	<	<
Traffic −1 month (Less Cure)	>	>	=	=	>
Minor Arterial TTC Class 4	<	< <	<	< <	< <
Local Road TTC Class 9	< <	< <	< <	< < <	< <
Initial IRI −13	=	=	=	=	< < <
Initial IRI +12	=	=	=	=	> > >

Table C-12. Results of Dry-Cold, AC-Thin, Traffic Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
AADT −18 (20%)	< <	< <	< <	< <	< <
AADT +8 (20%)	> >	> >	> >	> >	> >
Lane Width 2' Less	=	=	=	=	=
Lane Width 2' More	=	=	=	=	=
Wander 2" Less	> >	> >	> >	> >	> >
Wander 2" More	< <	< <	<	<	< <
Wheel Loca 4" Close to Ln Mrk	=	=	=	=	=
Wheel Loca 4" Far to Ln Mrk	=	=	=	=	=
All Tire Press +30 psi	> > >	> > >	> > >	> >	> > >
All Tire Press −30 psi	< < <	< < <	< < <	< < <	< < <
Dual Tire Press +30 psi	> > >	> > >	> > >	> >	> > >
Dual Tire Press −30 psi	< < <	< < <	< < <	< < <	< < <
Single Tire Press +30 psi	=	=	=	=	=
Single Tire Press −30 psi	=	=	=	=	=

Table C-13. Results of Dry-Cold, AC-Thin, Climate Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
Elevation −1500'	>>>	>>>	<	<	>>>
Elevation +1500'	>>>	>>>	>>>	>>	<<
Latitude −0.8	>	<	>	=	<
Latitude +0.6	=	>>	<<	<	>>>
Longitude +1	<<	<<	>>	<	<
Longitude −1	>>>	>>>	>>	>>	>>>
Water Table Depth at 1'	>>	>>	>	<<<	>>
Water Table Depth at 100'	=	=	=	>>	=
Water Table Depth at 50'	=	=	=	>>	=
Surface Shortwave Absorp −0.05	>	>	>>	<	>
Surface Shortwave Absorp +0.05	>	<	>>	>	<

Table C-14. Results of Dry-Cold, AC-Thin, AC Thermal Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
Thermal Agg Coeff Contr×0.6	=	=	=	=	=
Thermal Agg Coeff Contr×1.4	=	=	=	=	=
Thermal Ave Tens Str +78	=	=	=	=	=
Thermal Ave Tens Str −62	=	=	=	=	=
Thermal Lev 1 Creep Def	=	=	=	=	=
Thermal Lev 1 Creep Def×0.2	=	=	=	=	>
Thermal Lev 1 Creep Def×5	=	=	=	=	=
Thermal Lev 2 Creep Def	=	=	=	=	=
Thermal Lev 2 Creep Def×0.2	=	=	=	=	>
Thermal Lev 2 Creep Def×5	=	=	=	=	=
Thermal Mix Coeff Contr×0.1	=	=	=	=	=
Thermal Mix Coeff Contr×10	=	=	=	=	=
Thermal Mix VMA +1.7%	=	=	=	=	=
Thermal Mix VMA −1.7%	=	=	=	=	=

Table C-15. Results of Dry-Cold, AC-Thin, AC Binder Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
AC Layer +0.5"	<<<	<<	>>>	>>	<<
AC Layer +1.5"	<<<	>>>	>>>	>	>>>
AC Layer −0.5"	>>>	>>>	<<<	<<	>>>
Absolute Visc +200	=	=	=	=	<
Absolute Visc −200	=	>	=	=	=
Brookfield Visc ×0.83	=	>	=	=	=
Brookfield Visc ×1.17	=	<	>	>	<
Kinematic Visc +25	=	>	=	=	=
Kinematic Visc −25	=	<	>	>	<
Penetration +30	=	>	<	<	>
Penetration −10	=	<	>	>	<
Softening Point +10 °F	=	<	>	>	<
Softening Point −10 °F	=	>	=	<	=
Specific Gravity @77°F +0.02	=	>	=	=	=
Specific Gravity @77°F −0.02	=	=	=	=	<
Visc Graded Level 1 Def	<	>>	<<	<<	>>
AC Visc Grade 10	<	>	>	>	>
AC Visc Grade 20	<	>	<<	<<	>
AC Visc Grade 5	<	<	>>	>>	<
AC G* Delta (Default)	=	=	=	=	=
AC G* Delta×3	>	<	>>	>>	<
AC G* Delta/3	<	>	<<	<<	>
AC PG Grade 58-34	>	<	>>>	>>	<
AC PG Grade 64-22	<	>	<	<	>
AC PG Grade 76-22	<	>	<<<	<<	>>

Table C-16. Results of Dry-Cold, AC-Thin, General AC Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
AC Air Voids +3.8%	> > >	> > >	> > >	> >	> > >
AC Air Voids −1.7%	< < <	< < <	> >	<	< < <
AC Eff Binder Cont +3%	< < <	< < <	> >	>	< < <
AC Eff Binder Cont −3%	> > >	> > >	< <	< <	> > >
AC Heat Capacity +0.08	< <	< <	< <	<	< <
AC Heat Capacity +0.17	< <	< <	< <	< <	< <
AC Poisson's Ratio −0.05	> >	<	> >	> >	=
AC Poisson's Ratio +0.05	< <	>	< <	< <	>
AC Ref Temp +5 °F	=	=	=	=	=
AC Ref Temp −5 °F	=	=	=	=	=
AC Thermal Conductivity −0.14	>	>	>	=	>
AC Thermal Conductivity +0.14	< <	< <	<	<	< <
AC Unit Wt +6 pcf	=	=	=	<	=
AC Unit Wt −6 pcf	=	>	=	=	>

Table C-17. Results of Dry-Cold, AC-Thin, AC Mix Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
AC % Pass #200 −2.5%	>	<	> >	> >	<
AC % Pass #200 +2.5%	<	>	<	<	>
AC % Retained #4 +10%	>	<	> >	> >	<
AC % Retained #4 −10%	<	>	< <	< <	>
AC % Retained 3/4" +2%	<	>	<	<	>
AC % Retained 3/4" −3%	>	<	>	>	<
AC % Retained 3/8" +8%	<	>	<	<	>
AC % Retained 3/8" −7%	>	<	>	>	<
AC All Gradations Hi Side	<	>	=	<	>
AC All Gradations Low Side	>	<	> >	>	<
AC Dynamic Mod Def	< <	> >	< <	< <	> >
AC Dynamic Mod/1.5	> >	< <	> > >	> >	< <
AC Dynamic Mod×1.5	< <	> >	< < <	< <	> >

Table C-18. Results of Dry-Cold, AC-Thin, Crushed Stone, ICM Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
CS D60×0.825	=	<	=	=	=
CS D60×1.175	< <	<	<	<	<
CS Def Soil Water Value	< <	> >	>	>	> >
CS Grav Water Con −2%	<	<	=	<	<
CS Grav Water Con - Def	>	>	=	=	>
CS Grav Water Con +2%	<	<	=	<	<
CS High Soil Water Value	> > >	> > >	> > >	> > >	> > >
CS Low Soil Water Value	< < <	< <	< <	<	< <
CS P#4 +15%	>	>	=	=	>
CS P#4 −5%	=	=	=	=	=
CS P200 +3%	<	<	<	<	<
CS P200 −3%	< <	< <	=	<	< <
CS PI +3	<	<	<	<	<
CS PI −3	<	<	=	<	<
CS Sat Hyd Cond - Def	> > >	> > >	> >	> >	> > >
CS Sat Hyd Cond×5/12	< <	<	<	<	<
CS Sat Hyd Cond×1.5	>	>	=	=	>
CS Spec Grav - Default	>	>	=	=	>
CS Spec Grav −0.06	>	>	=	=	>
CS Spec Grav +0.06	>	>	=	=	>
CS Uncompacted	> > >	> > >	> >	>	> > >
CS Unit Wt −6 pcf	> >	> >	>	>	> >
CS Unit Wt - Default	=	=	=	=	=
CS Unit Wt +6 pcf	<	<	=	<	<

Table C-19. Results of Dry-Cold, AC-Thin, Crushed Stone, Strength Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
Crushed Stone Layer +1"	>	<	<	<<	<
Crushed Stone Layer −1"	>>>	>>>	>>	>>	>>>
CS Coeff Lateral Press −0.10	=	=	=	=	=
CS Coeff Lateral Press +0.10	=	=	=	=	=
CS Poisson's Ratio −0.05	<<	<<	<<	<	<<
CS Poisson's Ratio +0.05	>>	>>	>>	>	>>
CS Resilient Modulus×2	<<<	<<<	<<<	<<<	<<<
CS Resilient Modulus/2	>>>	>>>	>>>	>>>	>>>

Table C-20. Results of Dry-Cold, AC-Thin, Lime Treated ICM Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
CHLS D60×2	<	<	=	<	=
CHLS D60/4	>>>	>>>	>>	>>	>>>
CHLS Def Soil Water Value	>>>	>>>	>>	>>	>>>
CHLS Grav Water Con −3.2%	<<	<	<	<	<
CHLS Grav Water Con +2.8%	=	=	=	=	=
CHLS High Soil Water Value	>>	>>>	>>	>>	>>>
CHLS Low Soil Water Value	>>>	>>>	>>	>>	>>>
CHLS P#4 −10%	=	=	=	=	=
CHLS P#4 +5%	=	=	=	=	=
CHLS P200 +10%	=	<	=	<	>
CHLS P200 +70%	>>>	>>>	>>	>>	>>>
CHLS P200 −10%	>>>	>>>	>>	>>	>>>
CHLS PI +4	<	=	=	<	>
CHLS PI −2	<<	>>	<<	>	>>
CHLS Sat Hyd Cond/3.7	>>>	>>>	>>	>>	>>
CHLS Sat Hyd Cond×1.5	=	<	=	<	=
CHLS Sat Hyd Cond - Def	=	=	=	=	=
CHLS Spec Grav −0.06	=	>	=	=	>
CHLS Spec Grav +0.06	=	=	=	=	=
CHLS Uncompacted	<<	>	<	=	>
CHLS Unit Wt −12 pcf	<<	>	<	=	>
CHLS Unit Wt - Default	=	=	=	=	=
CHLS Unit Wt −8 pcf	>	=	=	=	=

Table C-21. Results of Dry-Cold, AC-Thin, Lime Treated Strength Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
CH Lime Stab Layer +2"	>>	<	>	>	<
CH Lime Stab Layer −2"	<<	>	<	<	>
CHLS Poisson’s Ratio −0.15	>	<	=	<<	<
CHLS Poisson’s Ratio +0.10	<	>	=	>>	>
CHLS Coeff Lateral Press −0.10	=	=	=	=	=
CHLS Coeff Lateral Press +0.10	=	=	=	=	=
CHLS Resilient Mod×0.7	<<	>>	<	>	>>
CHLS Resilient Mod×1.3	>>	<<	>	<	<<

Table C-22. Results of Dry-Cold, AC-Thin, Subgrade ICM Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
SG D60×3/5	>	=	=	=	=
SG D60×7/5	>	=	=	=	=
SG Def Soil Water Value	<	>	=	<	>
SG Grav Water Con −3.9%	<	<	=	=	<
SG Grav Water Con - Def	<	=	=	=	=
SG Grav Water Con +4.1%	<	<	=	=	<
SG High Soil Water Value	<<	<	<	<	<
SG Low Soil Water Value	>	>	=	>	>
SG P200 +10%	=	<	=	<	=
SG P200 −10%	>	=	=	=	=
SG PI +10	<	<	=	<	<
SG PI −10	>>>	>>>	>>	>>>	>>>
SG Rep Values (No ICM)	=	=	=	<	=
SG Sat Hyd Cond	>>	<	>	>	<
SG Sat Hyd Cond (Prog Def)	=	=	=	=	=
SG Sat Hyd Cond×10	>	<	>	>	<
SG Sat Hyd Cond/10	>>	<	>	>	<
SG Spec Grav - Default	>	>	=	=	>
SG Spec Grav −0.05	>	=	=	=	=
SG Spec Grav +0.05	=	=	=	=	=
SG Uncompacted	<<<	<<<	<<	<<	<<<
SG Unit Wt +9 psi	<	<	<	<	<
SG Unit Wt −11 psi	>>	>>>	>>	>>	>>>
SG Unit Wt - Default	>	=	=	=	=

Table C-23. Results of Dry-Cold, AC-Thin, Subgrade Strength Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
SG Coeff Lateral Press −0.10	>	=	=	=	=
SG Coeff Lateral Press +0.10	>	=	=	=	=
SG Poisson's Ratio −0.05	=	<	=	=	<
SG Poisson's Ratio +0.05	>	>	=	<	>
SG Resilient Modulus +5 ksi	> >	>	> >	> >	>
SG Resilient Modulus −5 ksi	< < <	<	< <	< < <	<
SG Thickness +25"	> >	>	< <	> > >	>
SG Thickness −25"	>	>	=	< <	>

Table C-24. Results of Dry-Cold, AC-Thin, Bedrock Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
BR Fractured	=	=	=	=	=
BR Poiss Ratio −0.05	=	=	=	=	=
BR Poiss Ratio +0.05	=	=	=	=	=
BR Res Mod −200,000	=	=	=	=	=
BR Res Mod +200,000	=	=	=	=	=
BR Unit Wt +20 pcf	=	=	=	=	=
BR Unit Wt −20 pcf	=	=	=	=	=

APPENDIX D

WET-WARM, AC THIN RESULTS

Table D-1. Wet-Warm, AC-Thin, Highly Significant Variables - Longitudinal Cracking.

Description	Category	Long-Rank
ALL Tire Press +30 psi	03-Traffic-General-Axle	0.3
ALL Tire Press −30 psi	03-Traffic-General-Axle	0.2
Dual Tire Press +30 psi	03-Traffic-General-Axle	0.3
Dual Tire Press −30 psi	03-Traffic-General-Axle	0.2
Water Table Depth 1'	04-Climate	0.4
AC Layer +0.5"	07-AC	0.2
AC Layer +1.5"	07-AC	0.1
AC Layer −0.5"	07-AC	0.1
AC Air Voids +3.8%	07-AC-General	0.1
AC Air Voids −1.7%	07-AC-General	0.3
AC Eff Binder Content +3%	07-AC-General	0.5
AC Eff Binder Content −3%	07-AC-General	0.2
CS Low Soil Water Values	08-CS-ICM	0.3
CS Uncompacted	08-CS-ICM	0.2
CS Unit Wt −6 pcf	08-CS-ICM	0.3
CS High Soil Water Values	08-CS-Str	0.1
CS Resilient Modulus×2	08-CS-Str	0.2
CS Resilient Modulus/2	08-CS-Str	0.1
CHLS D60/4	09-CHLS-ICM	0.3
CHLS High Soil Water Value	09-CHLS-ICM	0.5
CHLS Low Soil Water Value	09-CHLS-ICM	0.4
CHLS P200 +70%	09-CHLS-ICM	0.4
CHLS P200 −10%	09-CHLS-ICM	0.2
CHLS PI −2	09-CHLS-ICM	0.2
CHLS Uncompacted	09-CHLS-ICM	0.4
CHLS Unit Wt −12 pcf	09-CHLS-ICM	0.4
SG Unit Wt +23.4 psi	10-SG-ICM	0.5

Table D-2. Wet-Warm, AC-Thin, Significant Variables - Longitudinal Cracking.

Description	Category	Long-Rank
Local Road TTC Class 9	02-Site	0.8
AADT −18 (20%)	03-Traffic	1.0
AADT +18 (20%)	03-Traffic	1.0
Wander 2" LESS	03-Traffic-General	0.9
Wander 2" MORE	03-Traffic-General	1.9
Visc Graded Level 1 Def	07-AC-Binder-AC-1	0.8
AC Poisson's Ratio −0.05	07-AC-General	0.9
AC Poisson's Ratio +0.05	07-AC-General	0.8
AC % Retained #4 +10%	07-AC-Mix	2.4
AC % Retained #4 −10%	07-AC-Mix	2.4
AC Dynamic Mod/1.5	07-AC-Mix	0.9
AC Dynamic Modx 1.5	07-AC-Mix	0.6
CS Unit Wt +6 Pcf	08-CS-ICM	0.9
Crushed Stone Layer +1"	08-CS-Str	1.7
Crushed Stone Layer −1"	08-CS-Str	2.0
CS Poisson’s Ratio −0.05	08-CS-Str	1.9
CS Poisson’s Ratio + 0.05	08-CS-Str	1.8
CHLS Unit Wt +8 pcf	09-CHLS-ICM	0.7
CHLS Resilient Modulus×.7	09-CHLS-Str	1.4
CHLS Resilient Modulus×1.3	09-CHLS-Str	1.8
SG P200 +10%	10-SG-ICM	2.4
SG P200 −10%	10-SG-ICM	1.7
SG PI +10	10-SG-ICM	1.4
SG PI −10	10-SG-ICM	0.8
SG Uncompacted	10-SG-ICM	0.7
SG Unit Wt −16.7 psi	10-SG-ICM	0.7
SG Resilient Modulus +4 ksi	10-SG-Str	0.8
SG Resilient Modulus −2 ksi	10-SG-Str	1.2
SG Thickness +25"	10-SG-Str	1.9

Table D-3. Wet-Warm, AC-Thin, Highly Significant Variables - Alligator Cracking.

Description	Category	Allig-Rank
ALL Tire Press +30 psi	03-Traffic-General-Axle	0.3
ALL Tire Press −30 psi	03-Traffic-General-Axle	0.4
Dual Tire Press +30 psi	03-Traffic-General-Axle	0.3
Dual Tire Press −30 psi	03-Traffic-General-Axle	0.4
Water Table Depth 1'	04-Climate	0.2
AC Layer +1.5"	07-AC	0.4
AC Air Voids +3.8%	07-AC-General	0.2
AC Air Voids −1.7%	07-AC-General	0.4
AC Eff Binder Content +3%	07-AC-General	0.5
AC Eff Binder Content −3%	07-AC-General	0.2
CS Low Soil Water Values	08-CS-ICM	0.5
CS Uncompacted	08-CS-ICM	0.2
CS Unit Wt −6 pcf	08-CS-ICM	0.4
CS High Soil Water Values	08-CS-Str	0.2
CS Resilient Modulus×2	08-CS-Str	0.3
CS Resilient Modulus/2	08-CS-Str	0.1
CHLS D60/4	09-CHLS-ICM	0.4
CHLS P200 +70%	09-CHLS-ICM	0.4
CHLS P200 −10%	09-CHLS-ICM	0.2
CHLS PI −2	09-CHLS-ICM	0.2

Table D-4. Wet-Warm, AC-Thin, Significant Variables - Alligator Cracking.

Description	Category	Allig-Rank
Local Road TTC Class 9	02-Site	0.7
Minor Arterial TTC Class 4	02-Site	1.4
AADT −18 (20%)	03-Traffic	1.0
AADT +18 (20%)	03-Traffic	1.0
Wander 2" LESS	03-Traffic-General	1.4
Wander 2" MORE	03-Traffic-General	1.7
AC Layer −0.5"	07-AC	0.8
AC Dynamic Mod/1.5	07-AC-Mix	1.0
AC Dynamic Mod×1.5	07-AC-Mix	1.3
CS Unit Wt +6 pcf	08-CS-ICM	1.3
CS Poisson's Ratio −0.05	08-CS-Str	2.2
CS Poisson's Ratio +0.05	08-CS-Str	2.1
CHLS Grav Water Con −3.2%	09-CHLS-ICM	2.2
CHLS Low Soil Water Value	09-CHLS-ICM	0.7
CHLS Uncompacted	09-CHLS-ICM	0.8
CHLS Unit Wt −12 pcf	09-CHLS-ICM	0.8
CHLS Unit Wt +8 pcf	09-CHLS-ICM	1.0
CH Lime Stab Layer +2"	09-CHLS-Str	2.0
CH Lime Stab Layer −2"	09-CHLS-Str	1.4
SG Default Soil Water Values	10-SG-ICM	1.6
SG High Soil Water Values	10-SG-ICM	1.6
SG Low Soil Water Values	10-SG-ICM	1.6
SG PI −10	10-SG-ICM	1.1
SG Sat Hyd Cond×100	10-SG-ICM	2.1
SG Uncompacted	10-SG-ICM	2.0
SG Unit Wt +23.4 psi	10-SG-ICM	0.6
SG Unit Wt −16.7 psi	10-SG-ICM	1.8
BR Deleted	11-BR	1.0

Table D-5. Wet-Warm, AC-Thin, Highly Significant Variables - AC Rutting.

Description	Category	ACRut-Rank
ALL Tire Press +30 psi	03-Traffic-General-Axle	0.4
ALL Tire Press −30 psi	03-Traffic-General-Axle	0.3
Dual Tire Press +30 psi	03-Traffic-General-Axle	0.4
Dual Tire Press −30 psi	03-Traffic-General-Axle	0.3
AC Layer +0.5"	07-AC	0.2
AC Layer +1.5"	07-AC	0.1
AC Layer −0.5"	07-AC	0.1
AC Air Voids +3.8%	07-AC-General	0.5
AC Dynamic Mod/1.5	07-AC-Mix	0.3
AC Dynamic Mod×1.5	07-AC-Mix	0.3
CS Uncompacted	08-CS-ICM	0.5
CS High Soil Water Values	08-CS-Str	0.4
CS Resilient Modulus×2	08-CS-Str	0.3
CS Resilient Modulus/2	08-CS-Str	0.2
CHLS P200 −10%	09-CHLS-ICM	0.5
CHLS PI −2	09-CHLS-ICM	0.5

Table D-6. Wet-Warm, AC-Thin, Significant Variables - AC Rut Rank.

Description	Category	ACRut-Rank
Local Road TTC Class 9	02-Site	0.8
AADT −18 (20%)	03-Traffic	1.0
AADT +18 (20%)	03-Traffic	1.0
Wander 2" LESS	03-Traffic-General	1.7
Water Table Depth 1'	04-Climate	0.7
Surface Shortwave Absorp −0.05	06-Drain	2.3
Surface Shortwave Absorp +0.05	06-Drain	1.7
AC Visc Grade 10	07-AC-Binder-AC-3	0.6
AC Visc Grade 20	07-AC-Binder-AC-3	1.4
AC G* Delta×3	07-AC-Binder-SP-1	1.2
AC G* Delta/3	07-AC-Binder-SP-1	1.4
AC PG Grade 64-22	07-AC-Binder-SP-3	1.2
AC PG Grade 76-22 Def	07-AC-Binder-SP-3	1.4
AC PG Grade 82-28	07-AC-Binder-SP-3	1.0
AC Eff Binder Content +3%	07-AC-General	1.7
AC Eff Binder Content −3%	07-AC-General	1.4
AC Heat Capacity +0.17	07-AC-General	2.3
AC Poisson's Ratio −0.05	07-AC-General	2.3
AC % Pass #200 −2.5%	07-AC-Mix	1.7
AC % Retained #4 +10%	07-AC-Mix	1.4
AC % Retained #4 −10%	07-AC-Mix	1.7
AC All Gradations Low Side	07-AC-Mix	2.3
CS Low Soil Water Values	08-CS-ICM	0.9
CS Unit Wt −6 pcf	08-CS-ICM	0.9
CS Poisson's Ratio −0.05	08-CS-Str	2.3
CS Poisson's Ratio +0.05	08-CS-Str	1.4
CHLS D60/4	09-CHLS-ICM	0.8
CHLS High Soil Water Value	09-CHLS-ICM	2.3
CHLS Low Soil Water Value	09-CHLS-ICM	1.2
CHLS P200 +70%	09-CHLS-ICM	0.9
CHLS Uncompacted	09-CHLS-ICM	1.2
CHLS Unit Wt −12 pcf	09-CHLS-ICM	1.2
CHLS Unit Wt +8 pcf	09-CHLS-ICM	1.7
SG PI −10	10-SG-ICM	1.4
SG Uncompacted	10-SG-ICM	1.4
SG Unit Wt +23.4 psi	10-SG-ICM	1.0
SG Unit Wt −16.7 psi	10-SG-ICM	1.4
SG Resilient Modulus + 4 ksi	10-SG-Str	1.7
SG Thickness +25"	10-SG-Str	1.4

Table D-7. Wet-Warm, AC-Thin, Highly Significant Variables - Total Rutting Rank.

Description	Category	TotRut-Rank
Local Road TTC Class 9	02-Site	0.5
All Tire Press −30 psi	03-Traffic-General-Axle	0.5
Dual Tire Press −30 psi	03-Traffic-General-Axle	0.5
AC Dynamic Mod/1.5	07-AC-Mix	0.5
AC Dynamic Mod× 1.5	07-AC-Mix	0.5
CS Resilient Modulus×2	08-CS-Str	0.4
CS Resilient Modulus/2	08-CS-Str	0.4
SG Thickness +25"	10-SG-Str	0.4
BR Deleted	11-BR	0.5

Table D-8. Wet-Warm, AC-Thin, Significant Variables - Total Rutting Rank.

Description	Category	TotRut-Rank
Minor Arterial TTC Class 4	02-Site	0.9
AADT −18 (20%)	03-Traffic	0.9
AADT +18 (20%)	03-Traffic	1.1
Wander 2" LESS	03-Traffic-General	2.1
ALL Tire Press +30 psi	03-Traffic-General-Axle	0.8
Dual Tire Press +30 psi	03-Traffic-General-Axle	0.8
Water Table Depth 1'	04-Climate	0.7
AC Layer +0.5"	07-AC	0.9
AC Layer −0.5"	07-AC	0.7
AC Visc Grade 10	07-AC-Binder-AC-3	1.4
AC G*Delta/3	07-AC-Binder-SP-1	2.3
AC PG Grade 76-22 Def	07-AC-Binder-SP-3	2.3
AC PG Grade 82-28	07-AC-Binder-SP-3	2.1
AC Air Voids +3.8%	07-AC-General	1.1
AC Eff Binder Content −3%	07-AC-General	2.1
CS Low Soil Water Values	08-CS-ICM	1.0
CS Uncompacted	08-CS-ICM	0.9
CS Unit Wt −6 Pcf	08-CS-ICM	1.4
Crushed Stone Layer +1"	08-CS-Str	2.1
Crushed Stone Layer −1"	08-CS-Str	2.1
CS High Soil Water Values	08-CS-Str	0.7
CHLS D60/4	09-CHLS-ICM	1.4
CHLS Low Soil Water Value	09-CHLS-ICM	2.3
CHLS P200 +70%	09-CHLS-ICM	1.6
CHLS P200 −10%	09-CHLS-ICM	0.8
CHLS PI −2	09-CHLS-ICM	0.7
CHLS Uncompacted	09-CHLS-ICM	1.7
CHLS Unit Wt −12 pcf	09-CHLS-ICM	1.7
CHLS Poisson's Ratio −0.15	09-CHLS-Str	1.3
CHLS Poisson's Ratio +0.10	09-CHLS-Str	2.1
SG Default Soil Water Values	10-SG-ICM	0.9
SG High Soil Water Values	10-SG-ICM	0.9
SG Low Soil Water Values	10-SG-ICM	0.9
SG PI −10	10-SG-ICM	1.6
SG Uncompacted	10-SG-ICM	1.6
SG Unit Wt +23.4 psi	10-SG-ICM	0.9
SG Unit Wt −16.7 psi	10-SG-ICM	1.4
SG Resilient Modulus +4 ksi	10-SG-Str	0.8
SG Resilient Modulus −2 ksi	10-SG-Str	1.2
SG Thickness −25"	10-SG-Str	1.0

Table D-9. Wet-Warm, AC-Thin, Highly Significant Variables - IRI Rank.

Description	Category	IRI-Rank
Initial IRI +12	02-Analysis	0.3
Initial IRI −13	02-Analysis	0.3
ALL Tire Press +30 psi	03-Traffic-General-Axle	0.3
ALL Tire Press −30 psi	03-Traffic-General-Axle	0.3
Dual Tire Press +30 psi	03-Traffic-General-Axle	0.3
Dual Tire Press −30 psi	03-Traffic-General-Axle	0.3
Latitude −1.1	04-Climate	0.5
Longitude +0.7	04-Climate	0.5
Water Table Depth 1'	04-Climate	0.2
AC Layer +1.5"	07-AC	0.4
AC Air Voids +3.8%	07-AC-General	0.1
AC Air Voids −1.7%	07-AC-General	0.3
AC Eff Binder Content +3%	07-AC-General	0.5
AC Eff Binder Content −3%	07-AC-General	0.2
CS Low Soil Water Values	08-CS-ICM	0.5
CS Uncompacted	08-CS-ICM	0.2
CS Unit Wt −6 pcf	08-CS-ICM	0.4
CS High Soil Water Values	08-CS-Str	0.2
CS Resilient Modulus×2	08-CS-Str	0.2
CS Resilient Modulus/2	08-CS-Str	0.1
CHLS D60/4	09-CHLS-ICM	0.4
CHLS P200 +70%	09-CHLS-ICM	0.3
CHLS P200 −10%	09-CHLS-ICM	0.2
CHLS PI −2	09-CHLS-ICM	0.1
SG Unit Wt +23.4 psi	10-SG-ICM	0.5

Table D-10. Wet-Warm, AC-Thin, Significant Variables - IRI Rank.

Description	Category	IRI-Rank
Local Road TTC Class 9	02-Site	0.7
Minor Arterial TTC Class 4	02-Site	1.4
AADT −18 (20%)	03-Traffic	1.0
AADT +18 (20%)	03-Traffic	1.0
Wander 2" LESS	03-Traffic-General	1.4
Wander 2" MORE	03-Traffic-General	1.7
Latitude +0.6	04-Climate	2.3
Longitude −0.8	04-Climate	1.7
AC Layer +0.5"	07-AC	1.4
AC Layer −0.5"	07-AC	2.5
AC Dynamic Mod/1.5	07-AC-Mix	1.0
AC Dynamic Mod1.5	07-AC-Mix	1.0
CS Unit Wt + 6 pcf	08-CS-ICM	1.3
CS Poisson's Ratio −0.05	08-CS-Str	2.2
CS Poisson's Ratio +0.05	08-CS-Str	2.2
CHLS Grav Water Con −3.2%	09-CHLS-ICM	2.2
CHLS Low Soil Water Value	09-CHLS-ICM	0.7
CHLS Uncompacted	09-CHLS-ICM	0.8
CHLS Unit Wt −12 pcf	09-CHLS-ICM	0.8
CHLS Unit Wt +8 pcf	09-CHLS-ICM	1.0
CH Lime Stab Layer +2"	09-CHLS-Str	2.0
CH Lime Stab Layer −2"	09-CHLS-Str	1.3
SG Default Soil Water Values	10-SG-ICM	0.9
SG High Soil Water Values	10-SG-ICM	0.9
SG Low Soil Water Values	10-SG-ICM	0.9
SG P200 −10%	10-SG-ICM	2.2
SG PI +10	10-SG-ICM	2.2
SG PI −10	10-SG-ICM	1.0
SG Uncompacted	10-SG-ICM	1.2
SG Unit Wt −16.7 psi	10-SG-ICM	1.1
BR Deleted	11-BR	1.0

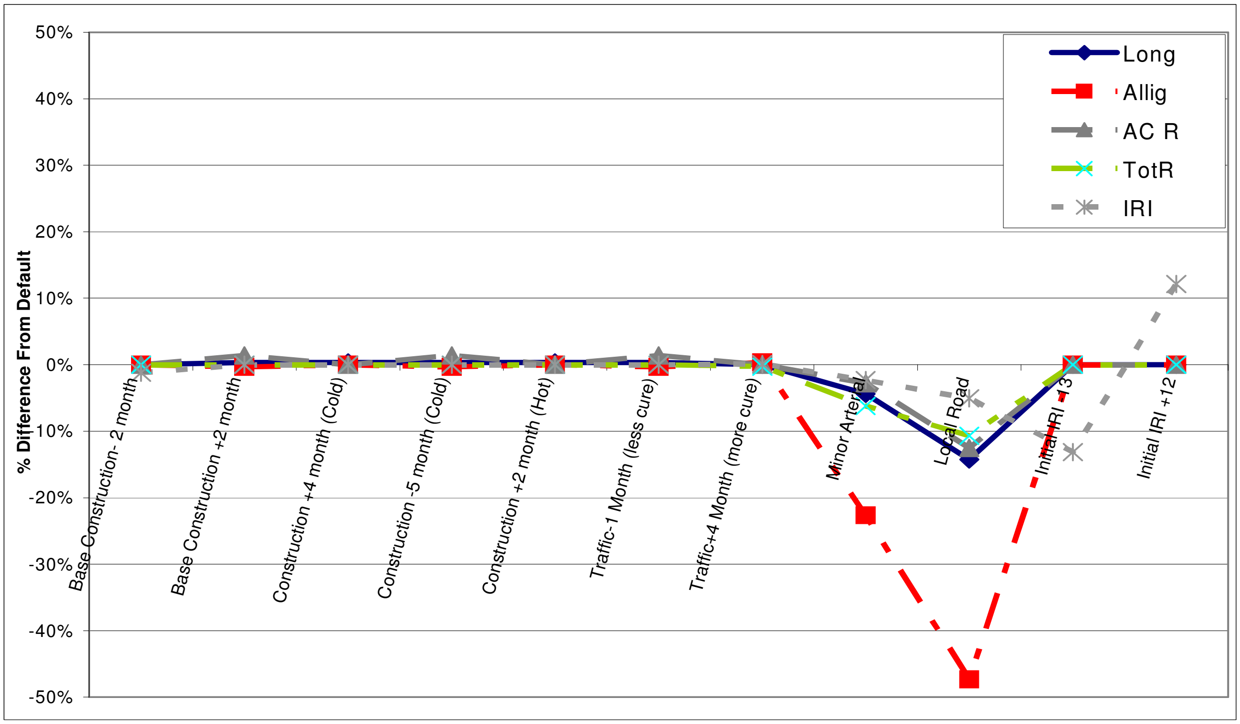

Figure D-1. Wet-Warm, AC-Thin, General Variables.

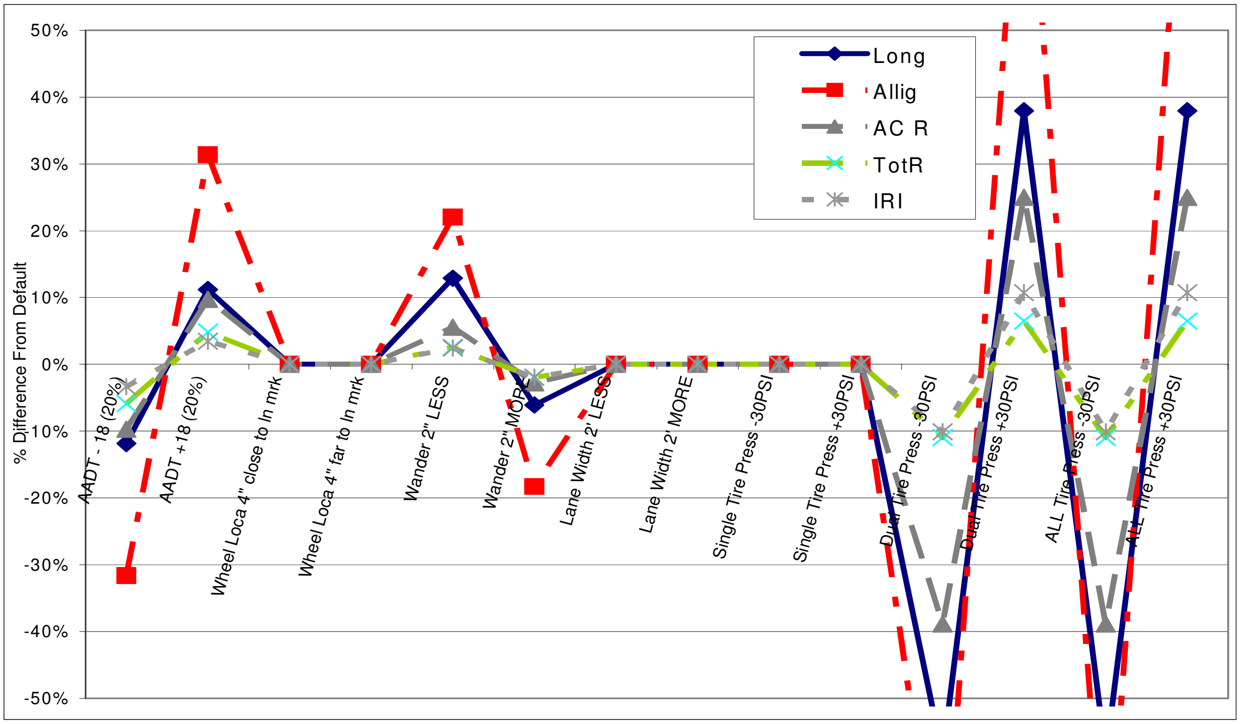

Figure D-2. Wet-Warm, AC-Thin, Traffic Variables.

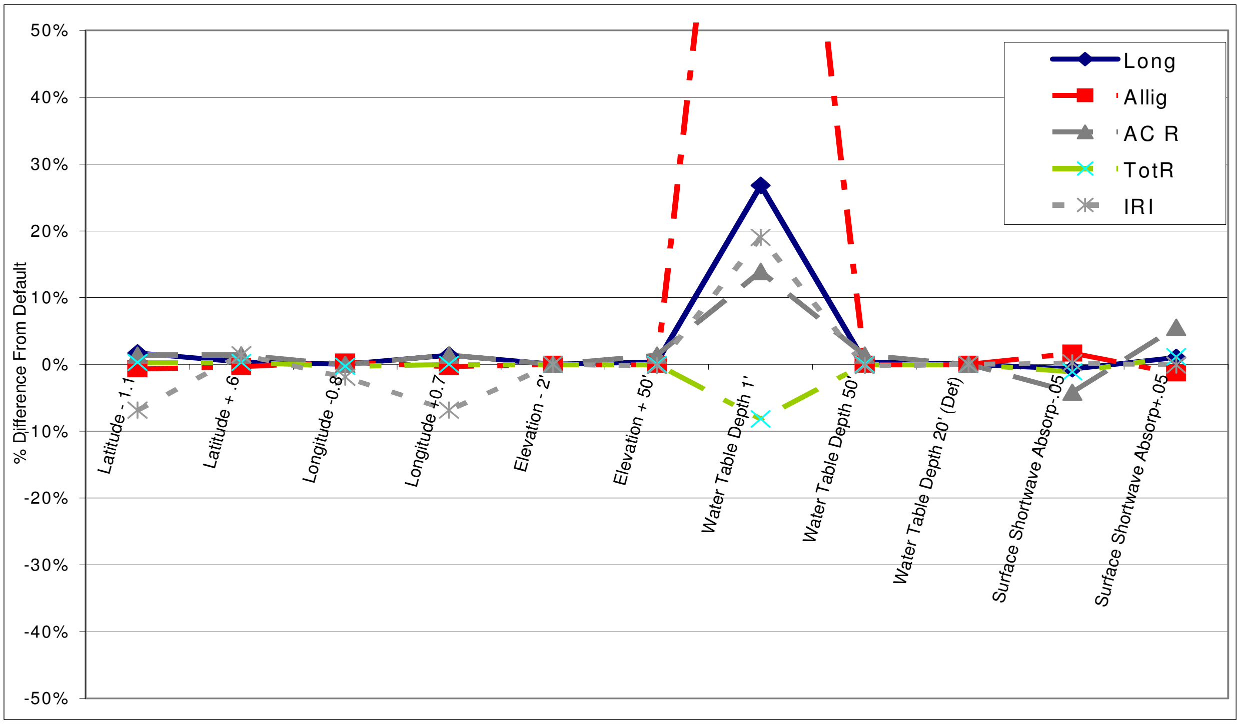

Figure D-3. Wet-Warm, AC-Thin, Climate Variables.

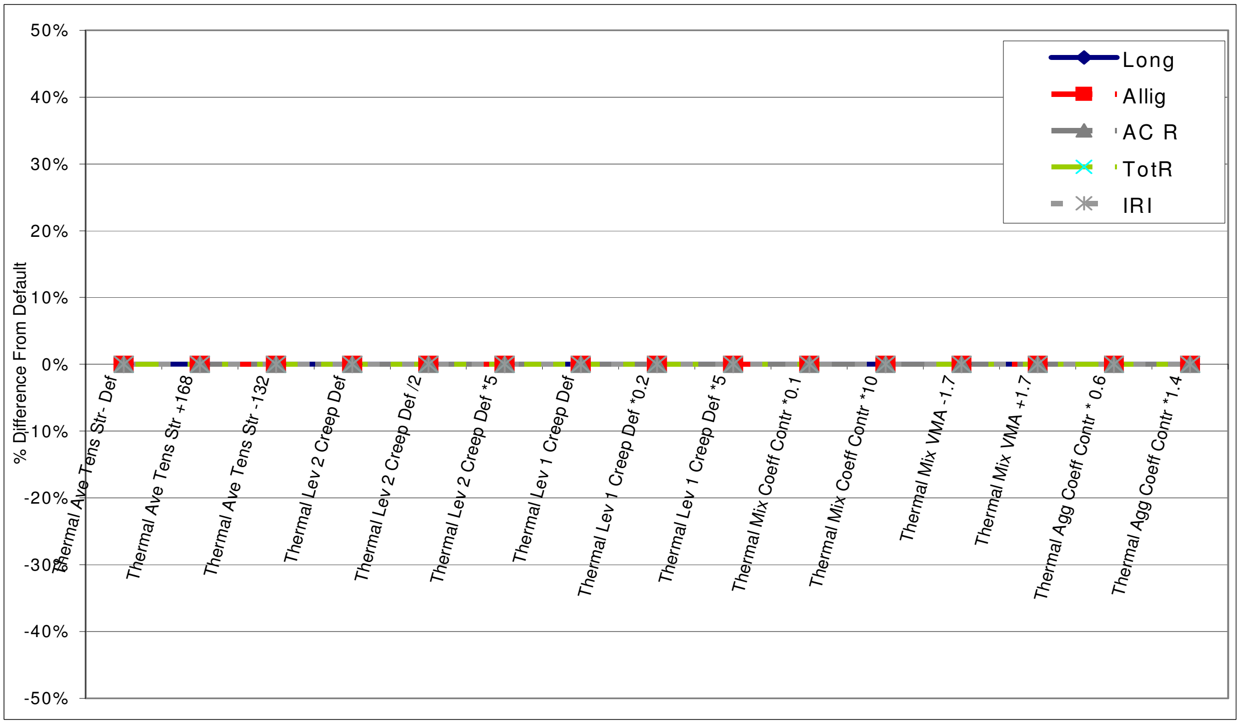

Figure D-4. Wet-Warm, AC-Thin, Thermal Variables.

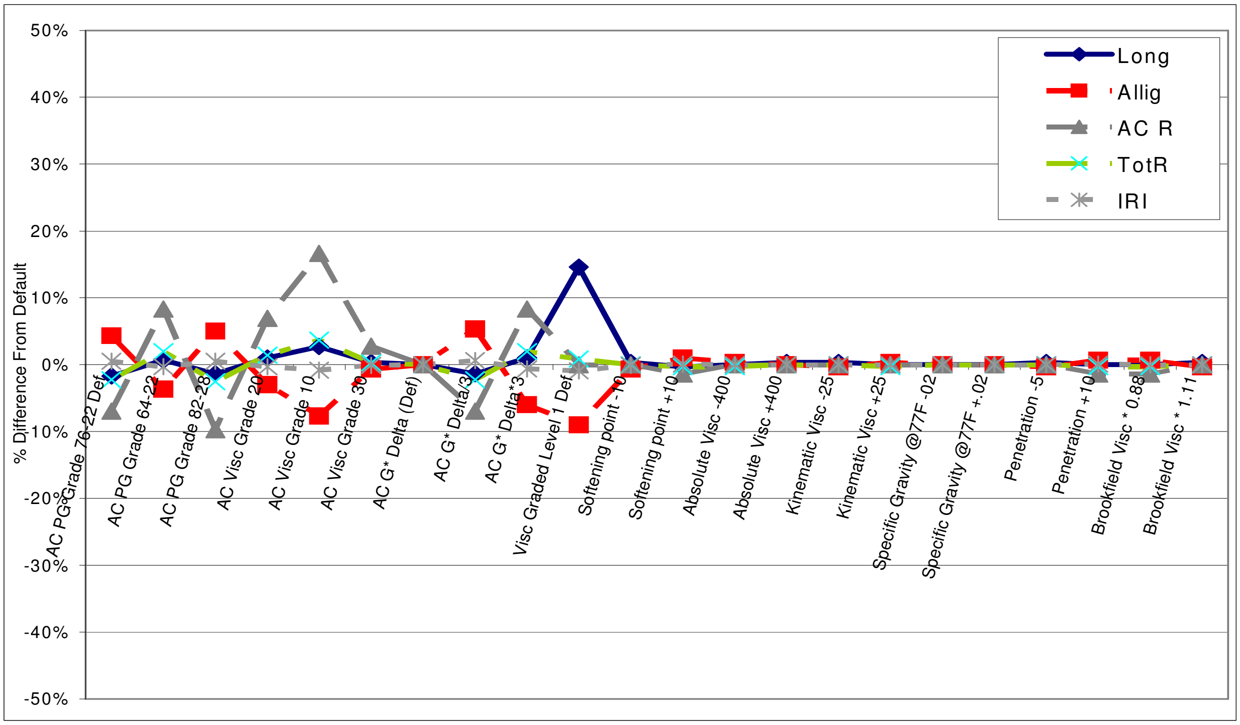

Figure D-5. Wet-Warm, AC-Thin, AC Binder Variables.

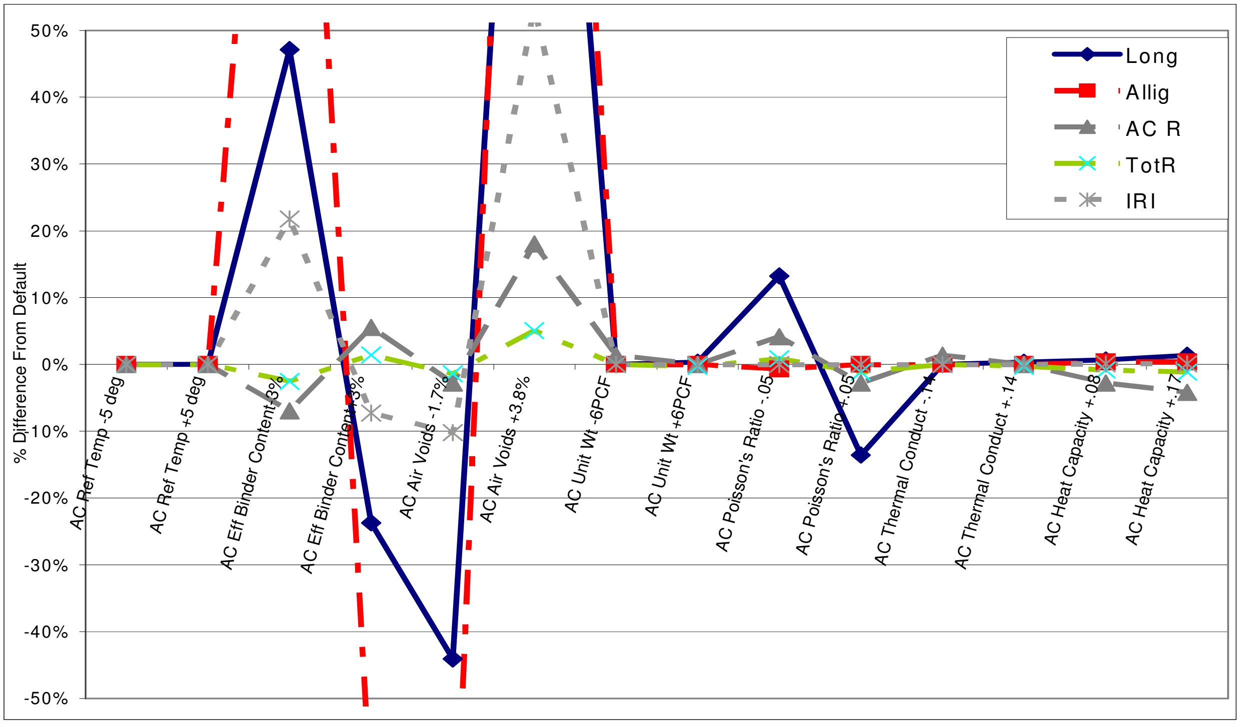

Figure D-6. Wet-Warm, AC-Thin, AC General Variables.

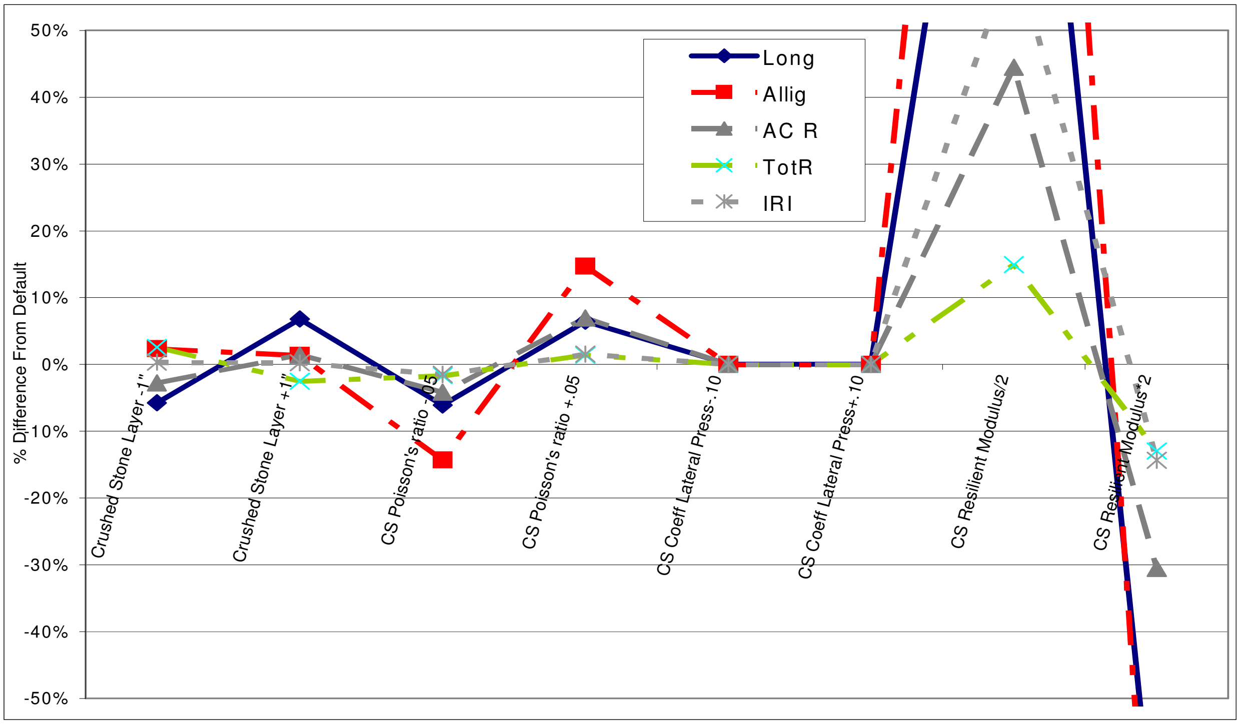

Figure D-7. Wet-Warm, AC-Thin, Crushed Stone Structural Variables.

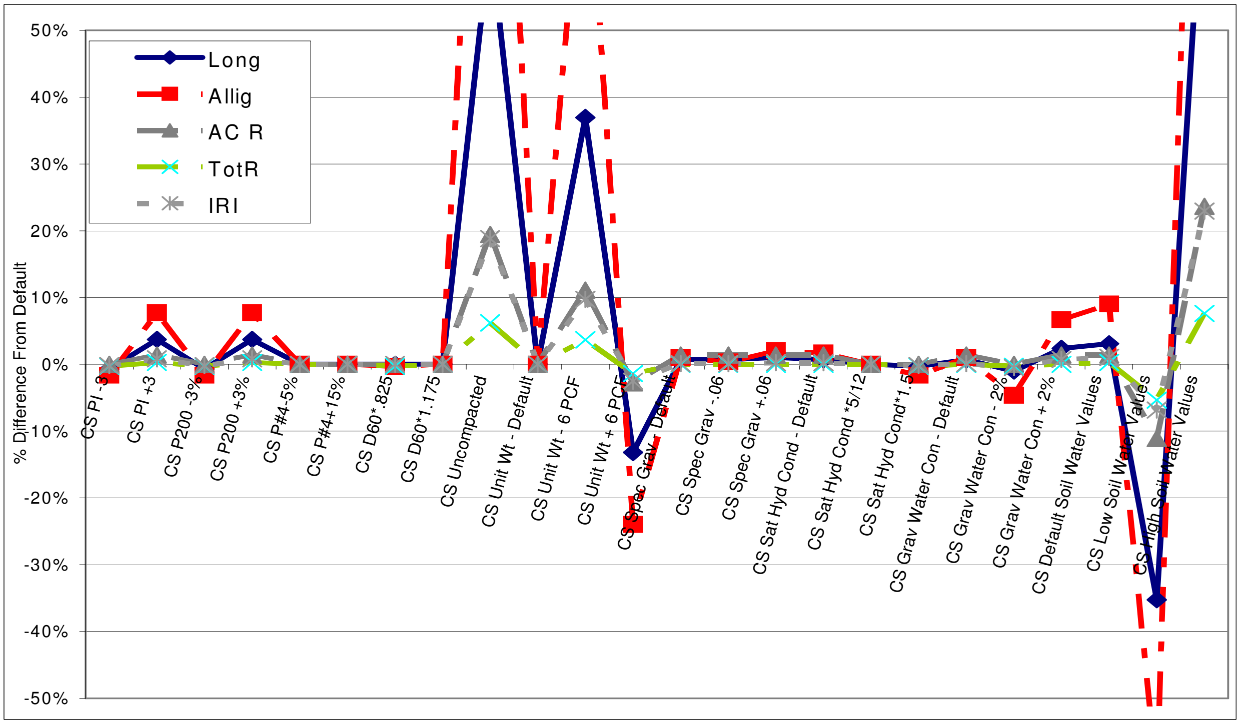

Figure D-8. Wet-Warm, AC-Thin, Crushed Stone Climatic Variables.

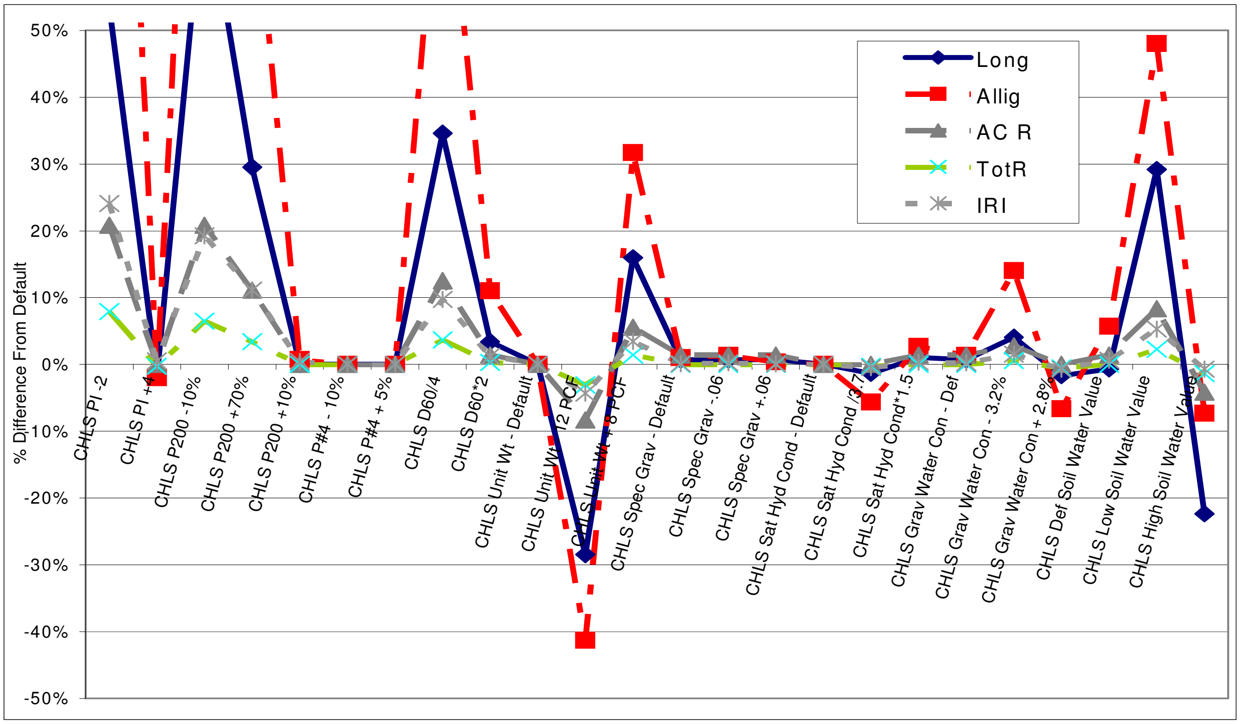

Figure D-9. Wet-Warm, AC-Thin, Lime Treated Climatic Variables.

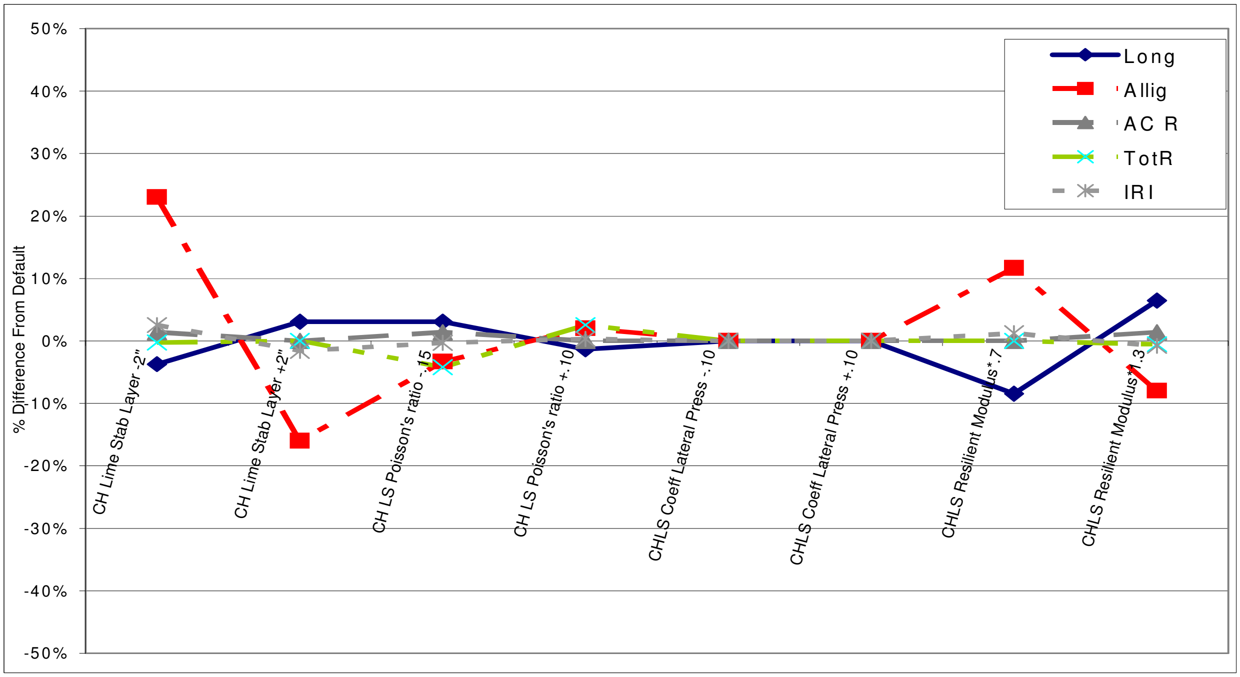

Figure D-10. Wet-Warm, AC-Thin, Lime Treated Structural Variables.

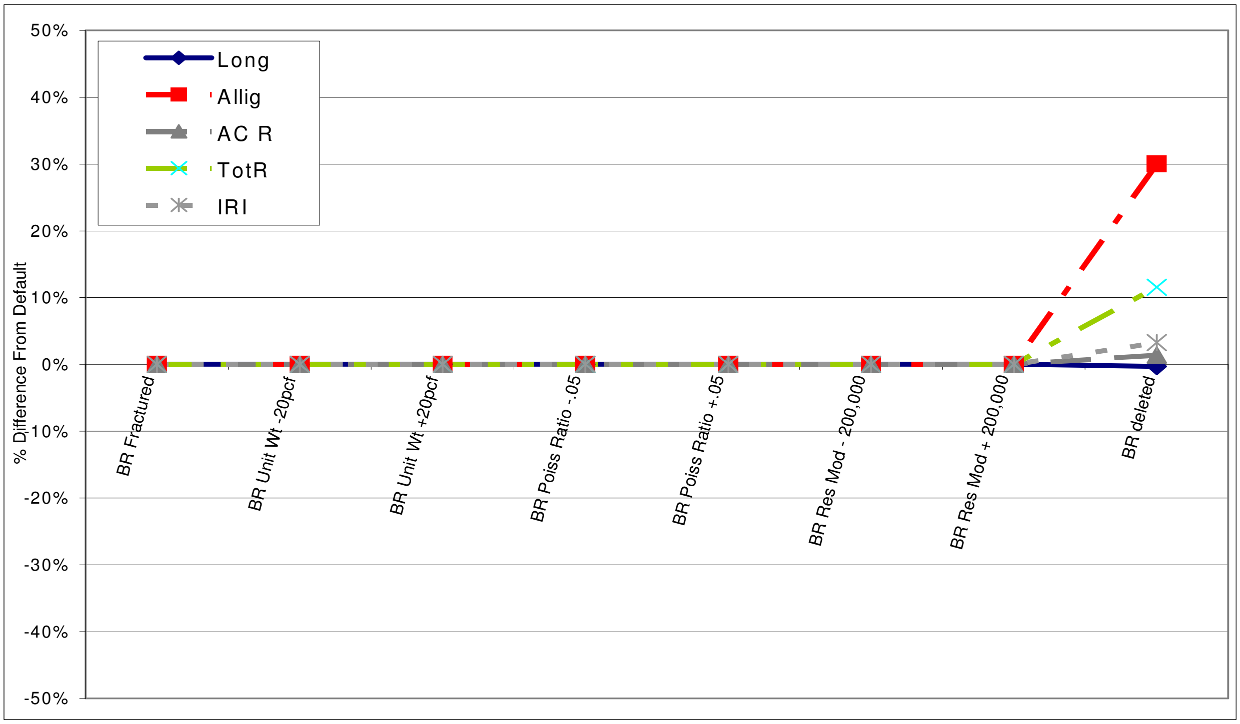

Figure D-11. Wet-Warm, AC-Thin, Bedrock Variables.

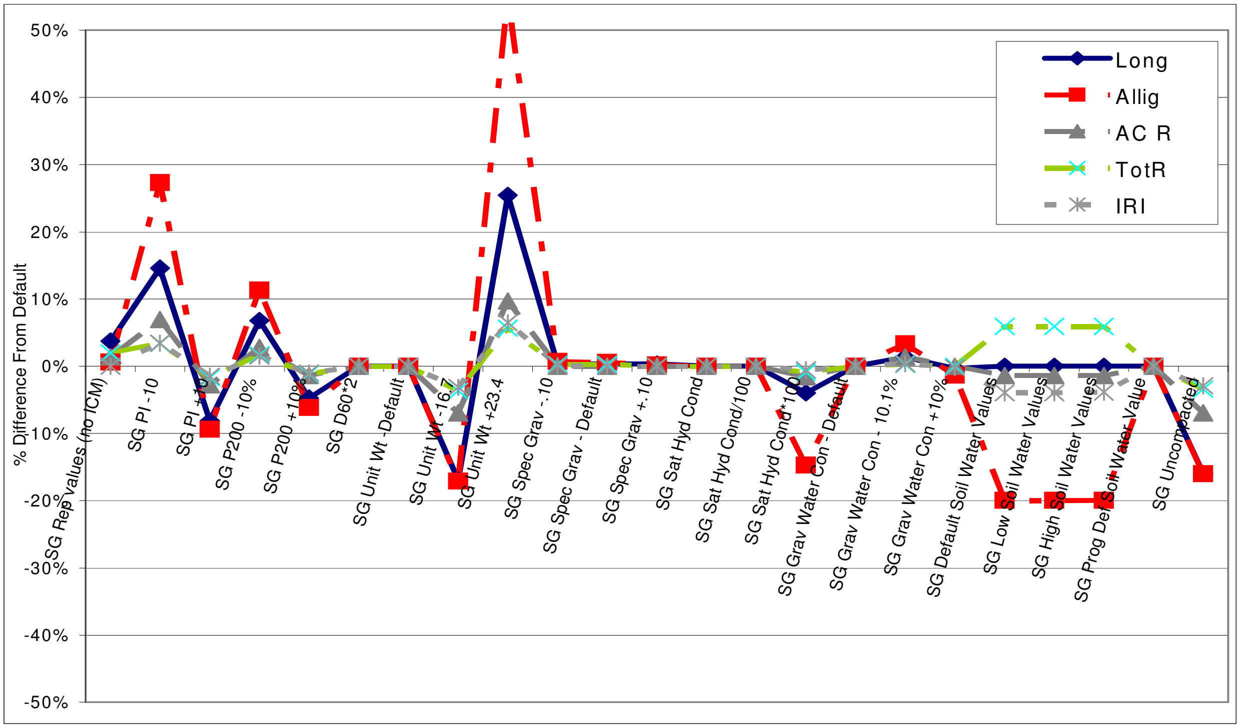

Figure D-12. Wet-Warm, AC Thin, Subgrade Climatic Variables.

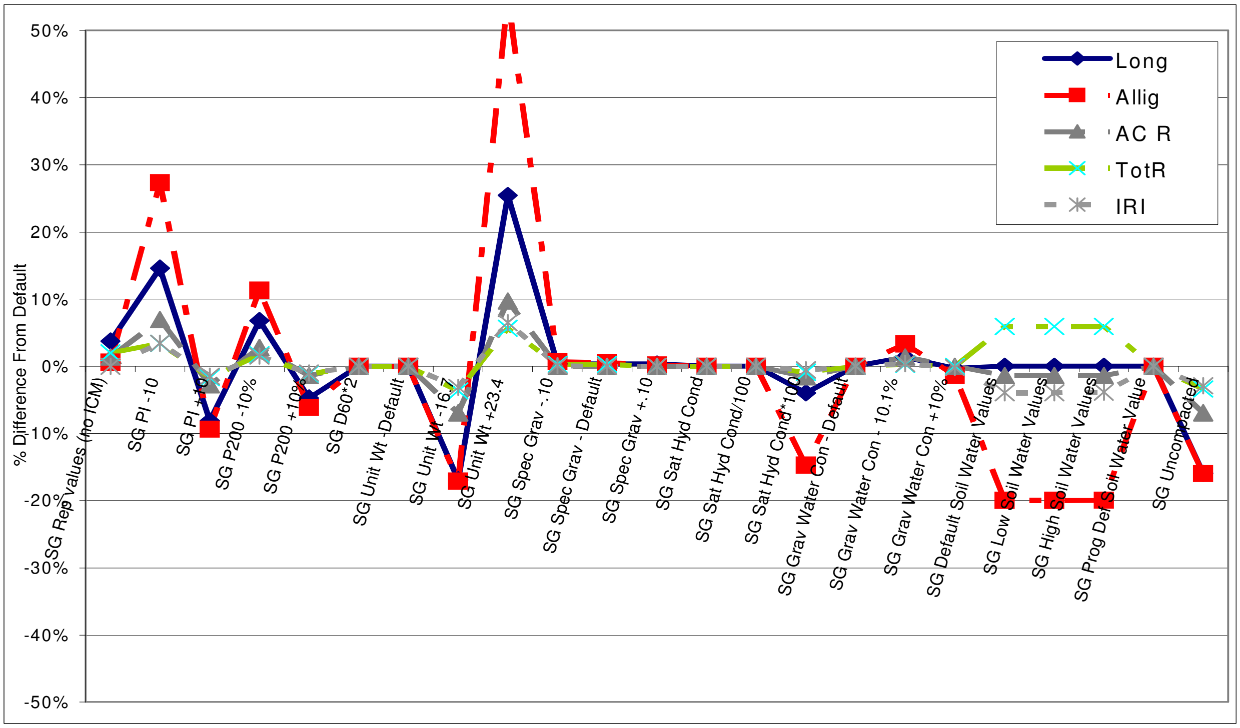

Figure D-13. Wet-Warm, AC-Thin, Subgrade Climatic Variables.

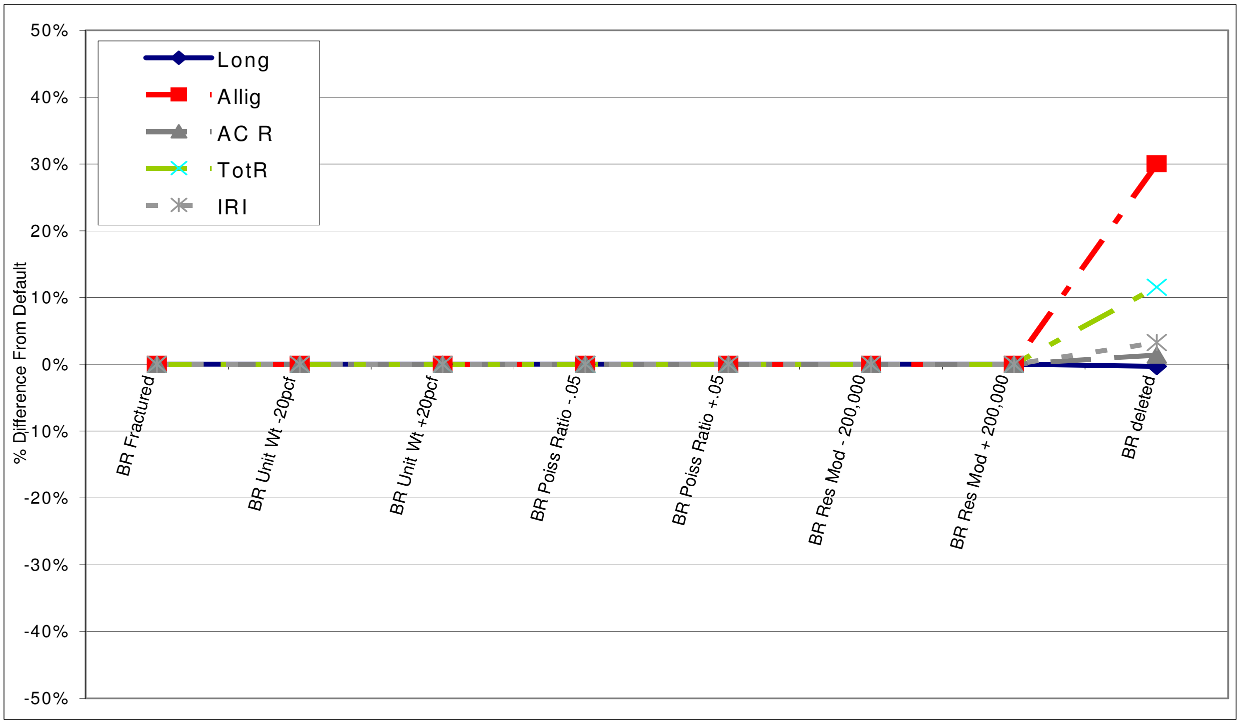

Figure D-14. Wet-Warm, AC-Thin, Bedrock Variables.

Table D-11. Results of Wet-Warm, AC-Thin, General Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
Base Construction −2 month	=	=	=	=	=
Base Construction +2 month	>	<	>	=	<
Construction +4 month	>	=	=	=	=
Construction −5 month	>	<	>	=	=
Construction +2 month	>	=	=	=	=
Traffic −1 Month (Less Cure)	>	<	>	=	=
Traffic +4 Month (More Cure)	=	>	=	<	>
Minor Arterial TTC Class 4	<	<<	<	<<	<<
Local Road TTC Class 9	<<	<<	<<	<<<	<<
Initial IRI −13	=	=	=	=	<<<
Initial IRI +12	=	=	=	=	>>>

Table D-12. Results of Wet-Warm, AC-Thin, Traffic Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
AADT −18 (20%)	<<	<<	<<	<<	<<
AADT +18 (20%)	>>	>>	>>	>>	>>
Lane Width 2' Less	=	=	=	=	=
Lane Width 2' More	=	=	=	=	=
Wander 2" Less	>>	>>	>>	>>	>>
Wander 2" More	<<	<<	<	<	<<
Wheel Loca 4" Close to Ln Mrk	=	=	=	=	=
Wheel Loca 4" Far to Ln Mrk	=	=	=	=	=
All Tire Press +30 psi	>>>	>>>	>>>	>>	>>>
All Tire Press −30 psi	<<<	<<<	<<<	<<<	<<<
Dual Tire Press +30 psi	>>>	>>>	>>>	>>	>>>
Dual Tire Press −30 psi	<<<	<<<	<<<	<<<	<<<
Single Tire Press +30 psi	=	=	=	=	=
Single Tire Press −30 psi	=	=	=	=	=

Table D-13. Results of Wet-Warm, AC-Thin, Climate Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
Elevation −2'	=	=	=	=	=
Elevation +50'	>	=	>	=	<
Latitude −1.1	>	<	>	>	<<<
Latitude +0.6	>	<	>	>	>>
Longitude +0.7	>	<	>	=	<<<
Longitude −0.8	=	>	=	<	<<
Water Table Depth 1'	>>>	>>>	>>	<<	>>>
Water Table Depth 50'	>	=	>	=	<
Surface Shortwave Absorp −0.05	<	>	<<	<	>
Surface Shortwave Absorp +0.05	>	<	>>	>	<

Table D-14. Results of Wet-Warm, AC-Thin, AC Thermal Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
Thermal Agg Coeff Contr×0.6	=	=	=	=	=
Thermal Agg Coeff Cont ×1.4	=	=	=	=	=
Thermal Ave Tens Str +168	=	=	=	=	=
Thermal Ave Tens Str −132	=	=	=	=	=
Thermal Ave Tens Str - Def	=	=	=	=	=
Thermal Lev 1 Creep Def	=	=	=	=	=
Thermal Lev 1 Creep Def×0.2	=	=	=	=	=
Thermal Lev 1 Creep Def×5	=	=	=	=	=
Thermal Lev 2 Creep Def	=	=	=	=	=
Thermal Lev 2 Creep Def×5	=	=	=	=	=
Thermal Lev 2 Creep Def/2	=	=	=	=	=
Thermal Mix Coeff Contr×0.1	=	=	=	=	=
Thermal Mix Coeff Contr×10	=	=	=	=	=
Thermal Mix VMA +1.7	=	=	=	=	=
Thermal Mix VMA −1.7	=	=	=	=	=

Table D-15. Results of Wet-Warm, AC-Thin, AC Binder Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
AC Layer +0.5"	<<<	<	>>>	>>	<<
AC Layer +1.5"	<<<	<<<	>>>	=	>>>
AC Layer −0.5"	>>>	<<	<<<	<<	<<
Absolute Visc +400	>	=	=	=	=
Absolute Visc −400	=	>	=	<	=
Brookfield Visc×0.88	=	>	<	<	=
Brookfield Visc×1.11	>	<	=	=	=
Kinematic Visc +25	=	>	=	<	=
Kinematic Visc −25	>	<	=	=	=
Penetration +10	=	>	<	<	>
Penetration −5	>	<	=	=	=
Softening Point +10 °F	<	>	<	<	>
Softening Point −10 °F	>	<	=	=	<
Specific Gravity @77°F +0.02	=	=	=	=	=
Specific Gravity @77°F −0.02	=	=	=	=	=
Visc Graded Level 1 Def	>>	<	=	>	<
AC Visc Grade 10	>	<	>>	>>	<
AC Visc Grade 20	>	<	>>	>	<
AC Visc Grade 30	>	<	>	>	<
AC G* Delta (Def)	=	=	=	=	=
AC G* Delta×3	>	<	>>	>	<
AC G* Delta/3	<	>	<<	<<	>
AC PG Grade 64-22	>	<	>>	>	<
AC PG Grade 76-22 Def	<	>	<<	<<	>
AC PG Grade 82-28	<	>	<<	<<	>

Table D-16. Results of Wet-Warm, AC-Thin, General AC Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
AC Air Voids +3.8%	> > >	> > >	> > >	> >	> > >
AC Air Voids −1.7%	< < <	< < <	<	<	< < <
AC Eff Binder Content +3%	< < <	< < <	> >	>	< < <
AC Eff Binder Content −3%	> > >	> > >	< <	< <	> > >
AC Heat Capacity +0.08	>	>	<	<	>
AC Heat Capacity +0.17	>	>	< <	<	>
AC Poisson’s Ratio −0.05	> >	>	> >	>	=
AC Poisson’s Ratio +0.05	< <	=	<	<	=
AC Ref Temp +5 °F	=	=	=	=	=
AC Ref Temp −5 °F	=	=	=	=	=
AC Thermal Conduct −0.14	=	=	>	=	=
AC Thermal Conduct +0.14	>	=	=	<	=
AC Unit Wt +6 pcf	>	=	=	<	=
AC Unit Wt −6 pcf	=	=	>	=	=

Table D-17. Results of Wet-Warm, AC-Thin, AC Mix Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
AC % Pass #200 −2.5%	>	<	> >	>	<
AC % Pass #200 +2.5%	<	>	<	<	>
AC % Retained #4 +10%	> >	<	> >	>	<
AC % Retained #4 −10%	< <	>	< <	<	>
AC % Retained 3/4" +2%	<	>	=	<	>
AC % Retained 3/4" −3%	>	<	>	>	<
AC % Retained 3/8" +8%	<	>	<	<	>
AC % Retained 3/8" −7%	>	<	>	>	<
AC All Gradations Hi Side	<	>	=	<	>
AC All Gradations Low Side	>	<	> >	>	<
AC Dynamic Mod Def	> >	< <	> > >	> >	< <
AC Dynamic Mod/1.5	> >	< <	> > >	> > >	< <
AC Dynamic Mod×1.5	< <	< <	> > >	> > >	< <

Table D-18. Results of Wet-Warm, AC-Thin, Crushed Stone, ICM Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
CS D60×0.825	=	<	=	<	=
CS D60×1.175	=	=	=	=	=
CS Default Soil Water Values	>	>	>	>	>
CS Grav Water Con −2%	<	<	=	<	<
CS Grav Water Con - Default	>	>	>	=	>
CS Grav Water Con +2%	>	>	>	=	>
CS Low Soil Water Values	< < <	< < <	< <	< <	< < <
CS P#4 +15%	=	=	=	=	=
CS P#4 −5%	=	=	=	=	=
CS P200 +3%	>	>	>	>	>
CS P200 −3%	<	<	=	<	<
CS PI +3	>	>	>	>	>
CS PI −3	<	<	=	<	<
CS Sat Hyd Cond - Default	>	>	>	=	>
CS Sat Hyd Cond×5/12	=	=	=	=	=
CS Sat Hyd Cond×1.5	<	<	=	<	<
CS Spec Grav - Default	>	>	>	=	>
CS Spec Grav −0.06	>	>	>	=	>
CS Spec Grav +0.06	>	>	>	=	>
CS Uncompacted	> > >	> > >	> > >	> >	> > >
CS Unit Wt −6 pcf	> > >	> > >	> >	> >	> > >
CS Unit Wt - Default	=	=	=	=	=
CS Unit Wt +6 pcf	< <	< <	<	<	< <

Table D-19. Results of Wet-Warm, AC-Thin, Crushed Stone, Strength Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
Crushed Stone Layer +1"	> >	>	>	< <	>
Crushed Stone Layer −1"	< <	>	<	> >	>
CS Coeff Lateral Press −0.10	=	=	=	=	=
CS Coeff Lateral Press +0.10	=	=	=	=	=
CS High Soil Water Values	> > >	> > >	> > >	> >	> > >
CS Poisson’s Ratio −0.05	< <	< <	< <	<	< <
CS Poisson’s Ratio +0.05	> >	> >	> >	>	> >
CS Resilient Modulus×2	< < <	< < <	< < <	< < <	< < <
CS Resilient Modulus/2	> > >	> > >	> > >	> > >	> > >

Table D-20. Results of Wet-Warm, AC-Thin, Lime Treated ICM Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
CHLS D60×2	>	>	>	>	>
CHLS D60/4	> > >	> > >	> >	> >	> > >
CHLS Def Soil Water Value	<	>	>	=	>
CHLS Grav Water Con −3.2%	>	> >	>	>	> >
CHLS Grav Water Con - Def	>	>	>	=	>
CHLS Grav Water Con +2.8%	<	<	=	<	<
CHLS High Soil Water Value	< < <	<	< <	<	<
CHLS Low Soil Water Value	> > >	> >	> >	> >	> >
CHLS P#4 −10%	=	=	=	=	=
CHLS P#4 +5%	=	=	=	=	=
CHLS P200 +10%	=	>	=	=	>
CHLS P200 +70%	> > >	> > >	> >	> >	> > >
CHLS P200 −10%	> > >	> > >	> > >	> >	> > >
CHLS PI +4	<	>	=	<	>
CHLS PI −2	> > >	> > >	> > >	> >	> > >
CHLS Sat Hyd Cond - Default	=	=	=	=	=
CHLS Sat Hyd Cond/3.7	<	<	=	<	<
CHLS Sat Hyd Cond×1.5	>	>	>	=	>
CHLS Spec Grav - Default	>	>	>	=	>
CHLS Spec Grav −0.06	>	>	>	=	>
CHLS Spec Grav +0.06	>	>	>	=	>
CHLS Uncompacted	< < <	< <	< <	< <	< <
CHLS Unit Wt −12 pcf	< < <	< <	< <	< <	< <
CHLS Unit Wt - Default	=	=	=	=	=
CHLS Unit Wt +8 pcf	> >	> >	> >	>	> >

Table D-21. Results of Wet-Warm, AC-Thin, Lime Treated Strength Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
CH Lime Stab Layer +2"	>	< <	=	=	< <
CH Lime Stab Layer −2"	<	> >	>	<	> >
CH LS Poisson’s Ratio −0.15	>	<	>	< <	<
CH LS Poisson’s Ratio +0.10	<	>	=	> >	>
CHLS Coeff Lateral Press −0.10	=	=	=	=	=
CHLS Coeff Lateral Press +0.10	=	=	=	=	=
CHLS Resilient Modulus×0.7	< <	>	=	=	>
CHLS Resilient Modulus×1.3	> >	<	>	<	<

Table D-22. Results of Wet-Warm, AC-Thin, Subgrade ICM Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
SG D60×2	=	=	=	=	=
SG Default Soil Water Values	=	< <	<	> >	< <
SG Grav Water Con −10.1%	>	>	>	>	>
SG Grav Water Con - Default	=	=	=	=	=
SG Grav Water Con +10%	<	<	=	=	<
SG High Soil Water Values	=	< <	<	> >	< <
SG Low Soil Water Values	=	< <	<	> >	< <
SG P200 +10%	< <	<	<	<	<
SG P200 −10%	> >	>	>	>	> >
SG PI +10	< <	<	<	<	< <
SG PI −10	> >	> >	> >	> >	> >
SG Prog Def Soil Water Value	=	=	=	=	=
SG Rep Values (no ICM)	>	>	>	>	=
SG Sat Hyd Cond	=	=	=	=	=
SG Sat Hyd Cond×100	<	< <	<	<	<
SG Sat Hyd Cond/100	=	=	=	=	=
SG Spec Grav - Default	>	>	=	>	=
SG Spec Grav −0.10	>	>	=	>	>
SG Spec Grav +0.10	>	>	=	=	=
SG Uncompacted	< <	< <	< <	< <	< <
SG Unit Wt +23.4 psi	> > >	> >	> >	> >	> > >
SG Unit Wt −16.7 psi	< <	< <	< <	< <	< <
SG Unit Wt - Default	=	=	=	=	=

Table D-23. Results of Wet-Warm, AC-Thin, Subgrade Strength Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
SG Coeff of Lateral Press −0.10	=	=	=	=	=
SG Coeff of Lateral Press +0.10	=	=	=	=	=
SG Poisson's Ratio −0.05	=	<	=	=	<
SG Poisson's Ratio +0.05	>	>	>	<	=
SG Resilient Modulus +4 ksi	> >	>	> >	> >	>
SG Resilient Modulus −2 ksi	< <	<	<	< <	<
SG Thickness +25"	> >	>	< <	> > >	>
SG Thickness −25"	>	>	>	< <	>

Table D-24. Results of Wet-Warm, AC-Thin, Bedrock Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
BR Deleted	<	> >	>	> > >	> >
BR Fractured	=	=	=	=	=
BR Poiss Ratio −0.05	=	=	=	=	=
BR Poiss Ratio +0.05	=	=	=	=	=
BR Res Mod −200,000	=	=	=	=	=
BR Res Mod +200,000	=	=	=	=	=
BR Unit Wt +20 pcf	=	=	=	=	=
BR Unit Wt −20 pcf	=	=	=	=	=

APPENDIX E

DRY-COLD, AC-INTERMEDIATE RESULTS

Table E-1. Dry-Cold, AC-Intermediate, Highly Significant Variables - Longitudinal Cracking.

Description	Category	Long-Rank
Base Construction −2 month	01-General	0.1
Construction −5 month	01-General	0.1
Local Road TTC Class 9	02-Site	0.3
Minor Arterial TTC Class 4	02-Site	0.5
Elevation −1500'	04-Climate	0.1
Latitude +0.6	04-Climate	0.1
Longitude −1	04-Climate	0.4
Water Table Depth 1'	04-Climate	0.5
AC Layer +1.5"	07-AC	0.2
AC Layer −1.5"	07-AC	0.2
Visc Graded Level 1 Def	07-AC-Binder-AC-1	0.5
AC PG Grade 76-22	07-AC-Binder-SP-3	0.3
AC Air Voids +3.8%	07-AC-General	0.1
AC Air Voids −1.7%	07-AC-General	0.2
AC Eff Binder Content +3%	07-AC-General	0.4
AC Eff Binder Content −3%	07-AC-General	0.4
AC Dynamic Mod/1.5	07-AC-Mix	0.3
AC Dynamic Mod Def	07-AC-Mix	0.3
AC Dynamic Mod×1.5	07-AC-Mix	0.2
CS Low Soil Water Value	08-CS-ICM	0.5
CS Uncompacted	08-CS-ICM	0.4
CS High Soil Water Value	08-CS-ICM	0.4
CS Resilient Modulus×2	08-CS-Str	0.1
CS Resilient Modulus/2	08-CS-Str	0.2
CHLS PI −2	09-CHLS-ICM	0.4
SG Def Soil Water Value	10-SG-ICM	0.4
SG PI +10	10-SG-ICM	0.2
SG Sat Hyd Cond	10-SG-ICM	0.2
SG Sat Hyd Cond×10	10-SG-ICM	0.2
SG Sat Hyd Cond/10	10-SG-ICM	0.2
SG Uncompacted	10-SG-ICM	0.2
SG Unit Wt −11 psi	10-SG-ICM	0.2
SG Resilient Modulus +5 ksi	10-SG-Str	0.5
SG Resilient Modulus −5 ksi	10-SG-Str	0.1

Table E-2. Dry-Cold, AC-Intermediate, Significant Variables - Longitudinal Cracking.

Description	Category	Long-Rank
AADT −193 (20%)	03-Traffic	1.0
AADT +232 (20%)	03-Traffic	1.0
Wander 2" Less	03-Traffic-General	1.3
Wander 2" More	03-Traffic-General	1.3
All Tire Press −30 psi	03-Traffic-General-Axle	2.2
Dual Tire Press −30 psi	03-Traffic-General-Axle	2.2
Elevation +1500'	04-Climate	1.1
Longitude +1	04-Climate	1.3
AC Visc Grade 20	07-AC-Binder-AC-3	0.9
AC Visc Grade 5	07-AC-Binder-AC-3	1.1
AC G* Delta×3	07-AC-Binder-SP-1	0.8
AC G* Delta/3	07-AC-Binder-SP-1	0.7
AC PG Grade 58-34	07-AC-Binder-SP-3	0.7
AC Poisson’s Ratio −0.05	07-AC-General	0.8
AC Poisson’s Ratio +0.05	07-AC-General	0.7
AC Thermal Conductivity +0.14	07-AC-General	1.8
AC % Pass #200 −2.5%	07-AC-Mix	1.3
AC % Pass #200 +2.5%	07-AC-Mix	2.2
AC % Retained #4 +10%	07-AC-Mix	1.3
AC % Retained #4 −10%	07-AC-Mix	1.3
AC All Gradations on Low Side	07-AC-Mix	1.8
CS Grav Water Con −2%	08-CS-ICM	2.2
CS Sat Hyd Cond - Default	08-CS-ICM	1.8
CS Unit Wt −6 pcf	08-CS-ICM	0.6
CS Unit Wt +6 pcf	08-CS-ICM	1.8
Crushed Stone Layer +1"	08-CS-Str	0.7
Crushed Stone Layer −1"	08-CS-Str	1.8
CS Poisson’s Ratio −0.05	08-CS-Str	2.2
CS Poisson’s Ratio +0.05	08-CS-Str	2.2
CHLS Def Soil Water Value	09-CHLS-ICM	1.5
CHLS High Soil Water Value	09-CHLS-ICM	1.5
CHLS Low Soil Water Value	09-CHLS-ICM	1.5
CHLS P200 +70%	09-CHLS-ICM	1.5
CHLS P200 −10%	09-CHLS-ICM	0.8
CHLS Unit Wt +8 pcf	09-CHLS-ICM	2.2
CH Lime Stab Layer +2"	09-CHLS-Str	0.7
CH Lime Stab Layer −2"	09-CHLS-Str	1.1
CH LS Poisson’s Ratio −0.15	09-CHLS-Str	1.8
CHLS Resilient Mod×0.7	09-CHLS-Str	0.8
CHLS Resilient Mod×1.3	09-CHLS-Str	0.8

Table E-2. Dry-Cold, AC-Intermediate, Significant Variables - Longitudinal Cracking (Continued).

SG D60×3/5	10-SG-ICM	1.3
SG D60×7/5	10-SG-ICM	1.3
SG Grav Water Con −3.9%	10-SG-ICM	1.3
SG Grav Water Con - Default	10-SG-ICM	1.3
SG Grav Water Con +4.1%	10-SG-ICM	1.3
SG High Soil Water Value	10-SG-ICM	1.3
SG P200 +10%	10-SG-ICM	0.8
SG P200 −10%	10-SG-ICM	1.8
SG Rep Values (no ICM)	10-SG-ICM	2.2
SG Sat Hyd Cond Prog Def×10	10-SG-ICM	0.7
SG Soil Water Value (Prog Def)	10-SG-ICM	1.3
SG Spec Grav - Def	10-SG-ICM	1.1
SG Spec Grav −0.05	10-SG-ICM	1.1
SG Spec Grav +0.05	10-SG-ICM	1.1
SG Unit Wt +9 pcf	10-SG-ICM	1.1
SG Unit Wt - Def	10-SG-ICM	1.3
SG Coeff of Lateral Press −0.10	10-SG-Str	1.3
SG Coeff of Lateral Press +0.10	10-SG-Str	1.3
SG Poisson’s Ratio −0.05	10-SG-Str	1.0
SG Poisson’s Ratio +0.05	10-SG-Str	1.8
SG Thickness +25"	10-SG-Str	2.2
SG Thickness −25"	10-SG-Str	1.3

Table E-3. Dry-Cold, AC-Intermediate, Highly Significant Variables - Alligator Cracking.

Description	Category	Allig-Rank
Base Construction −2 month	01-General	0.3
Construction −5 month	01-General	0.4
Elevation −1500'	04-Climate	0.3
Latitude +0.6	04-Climate	0.3
Water Table Depth 1'	04-Climate	0.4
AC Layer +1.5"	07-AC	0.3
AC Layer −1.5"	07-AC	0.2
AC Air Voids +3.8%	07-AC-General	0.1
AC Air Voids −1.7%	07-AC-General	0.2
AC Eff Binder Content +3%	07-AC-General	0.4
AC Eff Binder Content −3%	07-AC-General	0.2
CS Resilient Modulus×2	08-CS-Str	0.3
CS Resilient Modulus/2	08-CS-Str	0.3
SG PI −10	10-SG-ICM	0.3
SG Sat Hyd Cond	10-SG-ICM	0.4
SG Sat Hyd Cond×10	10-SG-ICM	0.4
SG Sat Hyd Cond/10	10-SG-ICM	0.4

Table E-4. Dry-Cold, AC-Intermediate, Significant Variables - Alligator Cracking.

Description	Category	Allig-Rank
Local Road TTC Class 9	02-Site	0.6
Minor Arterial TTC Class 4	02-Site	1.1
AADT −193 (20%)	03-Traffic	1.0
AADT +232 (20%)	03-Traffic	1.0
Wander 2" Less	03-Traffic-General	1.3
Wander 2" More	03-Traffic-General	1.4
All Tire Press −30 psi	03-Traffic-General-Axle	1.2
Dual Tire Press −30 psi	03-Traffic-General-Axle	1.2
Elevation +1500'	04-Climate	1.9
Longitude +1	04-Climate	2.3
Longitude −1	04-Climate	0.9
Visc Graded Level 1 Def	07-AC-Binder-AC-1	1.1
AC Visc Grade 20	07-AC-Binder-AC-3	2.0
AC Visc Grade 5	07-AC-Binder-AC-3	2.4
AC G* Delta×3	07-AC-Binder-SP-1	2.3
AC G* Delta/3	07-AC-Binder-SP-1	2.3
AC PG Grade 58-34	07-AC-Binder-SP-3	1.2
AC PG Grade 76-22	07-AC-Binder-SP-3	0.8
AC % Pass #200 −2.5%	07-AC-Mix	2.4
AC % Retained #4 +10%	07-AC-Mix	2.4
AC % Retained #4 −10%	07-AC-Mix	2.3
AC Dynamic Mod /1.5	07-AC-Mix	0.6
AC Dynamic Mod Def	07-AC-Mix	0.7
AC Dynamic Mod ×1.5	07-AC-Mix	0.7
CS High Soil Water Value	08-CS-ICM	0.7
CS Low Soil Water Value	08-CS-ICM	0.9
CS Uncompacted	08-CS-ICM	0.7
CS Unit Wt −6 pcf	08-CS-ICM	1.0
CHLS Def Soil Water Value	09-CHLS-ICM	2.4
CHLS High Soil Water Value	09-CHLS-ICM	1.2
CHLS P200 −10%	09-CHLS-ICM	1.0
CHLS PI −2	09-CHLS-ICM	0.6
CHLS Uncompacted	09-CHLS-ICM	2.1
CHLS Unit Wt −12 pcf	09-CHLS-ICM	2.1
CH Lime Stab Layer −2"	09-CHLS-Str	2.3
CHLS Resilient Mod×0.7	09-CHLS-Str	2.3
SG Def Soil Water Value	10-SG-ICM	1.4
SG PI +10	10-SG-ICM	0.7
SG Sat Hyd Cond Prog Def	10-SG-ICM	2.4
SG Uncompacted	10-SG-ICM	0.7
SG Unit Wt −11 pcf	10-SG-ICM	0.7
SG Resilient Modulus +5 ksi	10-SG-Str	1.3
SG Resilient Modulus −5 ksi	10-SG-Str	1.3

Table E-5. Dry-Cold, AC-Intermediate, Highly Significant Variables - AC Rutting.

Description	Category	ACRut-rank
All Tire Press +30 psi	03-Traffic-General-Axle	0.3
All Tire Press −30 psi	03-Traffic-General-Axle	0.2
Dual Tire Press +30 psi	03-Traffic-General-Axle	0.3
Dual Tire Press −30 psi	03-Traffic-General-Axle	0.2
Elevation −1500'	04-Climate	0.5
Elevation +1500'	04-Climate	0.5
AC Layer +1.5"	07-AC	0.3
Visc Graded Level 1 Def	07-AC-Binder-AC-1	0.4
AC Visc Grade 5	07-AC-Binder-AC-3	0.4
AC PG Grade 58-34	07-AC-Binder-SP-3	0.3
AC PG Grade 76-22	07-AC-Binder-SP-3	0.2
AC Air Voids +3.8%	07-AC-General	0.3
AC Poisson’s Ratio −0.05	07-AC-General	0.5
AC Poisson’s Ratio +0.05	07-AC-General	0.5
AC Dynamic Mod /1.5	07-AC-Mix	0.2
AC Dynamic Mod Def	07-AC-Mix	0.4
AC Dynamic Mod×1.5	07-AC-Mix	0.3
Crushed Stone Layer +1"	08-CS-Str	0.5
CH Lime Stab Layer +2"	09-CHLS-Str	0.5
SG Thickness +25"	10-SG-Str	0.4

Table E-6. Dry-Cold, AC-Intermediate, Significant Variables - AC Rutting.

Description	Category	ACRut-Rank
Local Road TTC Class 9	02-Site	0.7
Minor Arterial TTC Class 4	02-Site	2.3
AADT −193 (20%)	03-Traffic	1.1
AADT +232 (20%)	03-Traffic	0.9
Wander 2" Less	03-Traffic-General	1.5
Latitude +0.6	04-Climate	0.9
Longitude −1	04-Climate	1.2
Water Table Depth 1'	04-Climate	1.9
Surface Shortwave Absorp −0.05	06-Drain	1.3
Surface Shortwave Absorp +0.05	06-Drain	1.3
AC Layer −1.5"	07-AC	0.8
AC Visc Grade 20	07-AC-Binder-AC-3	0.6
AC G* Delta×3	07-AC-Binder-SP-1	0.7
AC G* Delta/3	07-AC-Binder-SP-1	0.8
AC Air Voids −1.7%	07-AC-General	1.1
AC Eff Binder Content +3%	07-AC-General	0.8
AC Eff Binder Content −3%	07-AC-General	0.6
AC Heat Capacity +0.08	07-AC-General	1.3
AC Heat Capacity +0.17	07-AC-General	0.8
AC % Pass #200 −2.5%	07-AC-Mix	0.7
AC % Pass #200 +2.5%	07-AC-Mix	1.5
AC % Retained #4 +10%	07-AC-Mix	0.7
AC % Retained #4 −10%	07-AC-Mix	0.8
AC % Retained 3/8" +8%	07-AC-Mix	2.0
AC % Retained 3/8" −7%	07-AC-Mix	2.1
AC All Gradations on Low Side	07-AC-Mix	1.1
CS Resilient Modulus×2	08-CS-Str	2.1
CS Resilient Modulus/2	08-CS-Str	2.3
SG PI −10	10-SG-ICM	1.4
SG Sat Hyd Cond	10-SG-ICM	2.1
SG Sat Hyd Cond×10	10-SG-ICM	2.1
SG Sat Hyd Cond/10	10-SG-ICM	2.4

Table E-7. Dry-Cold, AC-Intermediate, Highly Significant Variables - Total Rutting Rank.

Description	Category	TotR-Rank
Local Road TTC Class 9	02-Site	0.5
All Tire Press +30 psi	03-Traffic-General-Axle	0.4
All Tire Press −30 psi	03-Traffic-General-Axle	0.3
Dual Tire Press +30 psi	03-Traffic-General-Axle	0.4
Dual Tire Press −30 psi	03-Traffic-General-Axle	0.3
Elevation −1500'	04-Climate	0.5
Elevation +1500'	04-Climate	0.5
AC Layer +1.5"	07-AC	0.4
Visc Graded Level 1 Def	07-AC-Binder-AC-1	0.5
AC Visc Grade 5	07-AC-Binder-AC-3	0.5
AC PG Grade 58-34	07-AC-Binder-SP-3	0.3
AC PG Grade 76-22	07-AC-Binder-SP-3	0.2
AC Air Voids +3.8%	07-AC-General	0.3
AC Dynamic Mod/1.5	07-AC-Mix	0.2
AC Dynamic Mod Def	07-AC-Mix	0.4
AC Dynamic Mod ×1.5	07-AC-Mix	0.3

Table E-8. Dry-Cold, AC-Intermediate, Significant Variables - Total Rutting Rank.

Description	Category	TotR-Rank
Minor Arterial TTC Class 4	02-Site	1.1
AADT −193 (20%)	03-Traffic	1.0
AADT +232 (20%)	03-Traffic	1.0
Wander 2" Less	03-Traffic-General	1.6
Wander 2" More	03-Traffic-General	2.4
Latitude +0.6	04-Climate	0.8
Longitude −1	04-Climate	1.2
Water Table Depth 1'	04-Climate	1.2
Surface Shortwave Absorp −0.05	06-Drain	1.5
Surface Shortwave Absorp +0.05	06-Drain	1.5
AC Layer −1.5"	07-AC	0.6
AC Visc Grade 20	07-AC-Binder-AC-3	0.6
AC G* Delta×3	07-AC-Binder-SP-1	0.8
AC G* Delta/3	07-AC-Binder-SP-1	0.9
AC Air Voids −1.7%	07-AC-General	1.2
AC Eff Binder Content +3%	07-AC-General	0.9
AC Eff Binder Content −3%	07-AC-General	0.7
AC Heat Capacity +0.08	07-AC-General	1.6
AC Heat Capacity +0.17	07-AC-General	0.9
AC Poisson’s Ratio −0.05	07-AC-General	0.6
AC Poisson’s Ratio +0.05	07-AC-General	0.6
AC % Pass #200 −2.5%	07-AC-Mix	0.8
AC % Pass #200 +2.5%	07-AC-Mix	1.6
AC % Retained #4 +10%	07-AC-Mix	0.8
AC % Retained #4 −10%	07-AC-Mix	0.9
AC % Retained 3/8" +8%	07-AC-Mix	2.0
AC % Retained 3/8" −7%	07-AC-Mix	2.3
AC All Gradations on Low Side	07-AC-Mix	1.3
Crushed Stone Layer +1"	08-CS-Str	0.9
CH Lime Stab Layer +2"	09-CHLS-Str	1.0
SG PI −10	10-SG-ICM	2.4
SG Thickness +25"	10-SG-Str	1.9
SG Thickness −25"	10-SG-Str	1.2

Table E-9. Dry-Cold, AC-Intermediate, Highly Significant Variables - IRI Rank.

Description	Category	IRI-Rank
Base Construction - 2 month	01-General	0.5
Initial IRI +12	02-Analysis	0.1
Initial IRI −13	02-Analysis	0.1
Elevation +1500'	04-Climate	0.2
Water Table Depth 1'	04-Climate	0.3
AC Layer +1.5"	07-AC	0.3
AC Layer −1.5"	07-AC	0.2
AC Air Voids +3.8%	07-AC-General	0.0
AC Air Voids −1.7%	07-AC-General	0.3
AC Eff Binder Content +3%	07-AC-General	0.5
AC Eff Binder Content −3%	07-AC-General	0.2
CS Resilient Modulus×2	08-CS-Str	0.3
CS Resilient Modulus/2	08-CS-Str	0.3
SG PI −10	10-SG-ICM	0.4
SG Sat Hyd Cond	10-SG-ICM	0.4
SG Sat Hyd Cond×10	10-SG-ICM	0.4
SG Sat Hyd Cond/10	10-SG-ICM	0.5

Table E-10. Dry-Cold, AC-Intermediate, Significant Variables - IRI Rank.

Description	Category	IRI-Rank
Construction −5 month	01-General	0.6
Local Road TTC Class 9	02-Site	0.6
Minor Arterial TTC Class 4	02-Site	1.1
AADT −193 (20%)	03-Traffic	1.1
AADT +232 (20%)	03-Traffic	0.9
Wander 2" Less	03-Traffic-General	1.3
Wander 2" More	03-Traffic-General	1.5
All Tire Press +30 psi	03-Traffic-General-Axle	2.3
All Tire Press −30 psi	03-Traffic-General-Axle	1.2
Dual Tire Press +30 psi	03-Traffic-General-Axle	2.3
Dual Tire Press −30 psi	03-Traffic-General-Axle	1.2
Elevation −1500'	04-Climate	0.6
Latitude +0.6	04-Climate	0.8
Longitude −1	04-Climate	1.0
Visc Graded Level 1 Def	07-AC-Binder-AC-1	1.2
AC Visc Grade 20	07-AC-Binder-AC-3	2.0
AC Visc Grade 5	07-AC-Binder-AC-3	2.0
AC G* Delta×3	07-AC-Binder-SP-1	2.0
AC G* Delta/3	07-AC-Binder-SP-1	2.3
AC PG Grade 58-34	07-AC-Binder-SP-3	1.1
AC PG Grade 76-22	07-AC-Binder-SP-3	0.8
AC % Pass #200 −2.5%	07-AC-Mix	2.0
AC % Retained #4 +10%	07-AC-Mix	2.0
AC % Retained #4 −10%	07-AC-Mix	2.0
AC Dynamic Mod /1.5	07-AC-Mix	0.6
AC Dynamic Mod Def	07-AC-Mix	0.8
AC Dynamic Mod×1.5	07-AC-Mix	0.8
CS High Soil Water Value	08-CS-ICM	0.6
CS Low Soil Water Value	08-CS-ICM	1.0
CS Uncompacted	08-CS-ICM	0.6
CS Unit Wt −6 pcf	08-CS-ICM	1.0
CHLS Def Soil Water Value	09-CHLS-ICM	2.3
CHLS High Soil Water Value	09-CHLS-ICM	1.2
CHLS P200 +70%	09-CHLS-ICM	1.0
CHLS P200 −10%	09-CHLS-ICM	1.0
CHLS PI −2	09-CHLS-ICM	0.6
CHLS Uncompacted	09-CHLS-ICM	2.0
CHLS Unit Wt −12 pcf	09-CHLS-ICM	2.0
CHLS Unit Wt +8 pcf	09-CHLS-ICM	2.3
CH Lime Stab Layer −2"	09-CHLS-Str	2.0

Table E-10. Dry-Cold, AC-Intermediate, Significant Variables - IRI Rank (Continued).

CHLS Resilient Mod×0.7	09-CHLS-Str	1.8
SG Def Soil Water Value	10-SG-ICM	1.4
SG PI +10	10-SG-ICM	0.8
SG Sat Hyd Cond Prog Def×10	10-SG-ICM	2.3
SG Uncompacted	10-SG-ICM	0.7
SG Unit Wt +9 pcf	10-SG-ICM	2.3
SG Unit Wt −11pcf	10-SG-ICM	0.7
SG Resilient Modulus +5 ksi	10-SG-Str	1.4
SG Resilient Modulus −5 ksi	10-SG-Str	1.2

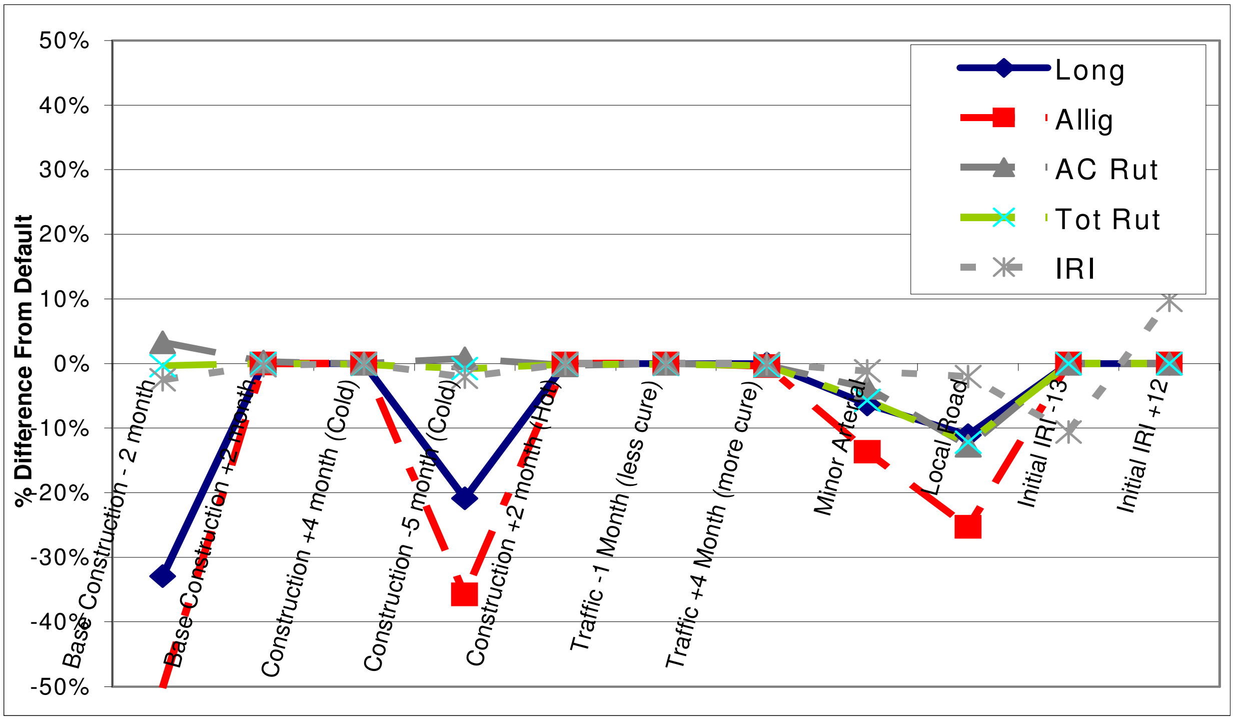

Figure E-1. Dry-Cold, AC-Intermediate, General Variables.

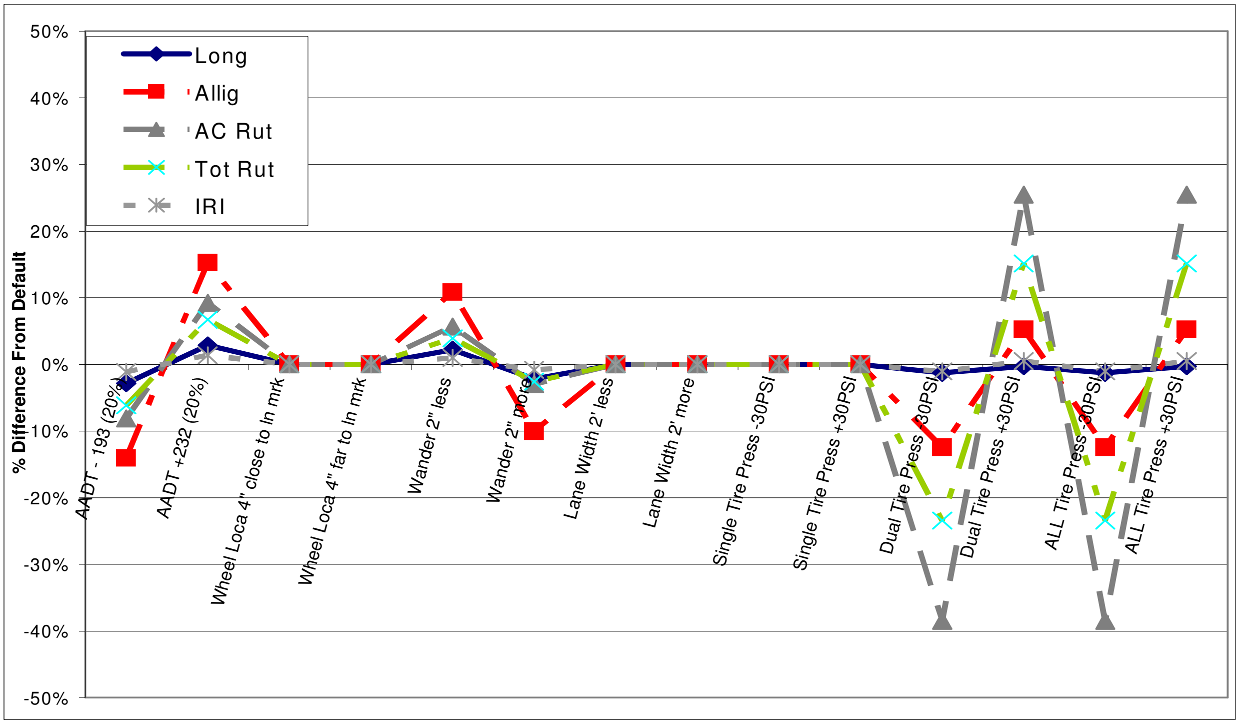

Figure E-2. Dry-Cold, AC-Intermediate, Traffic Variables.

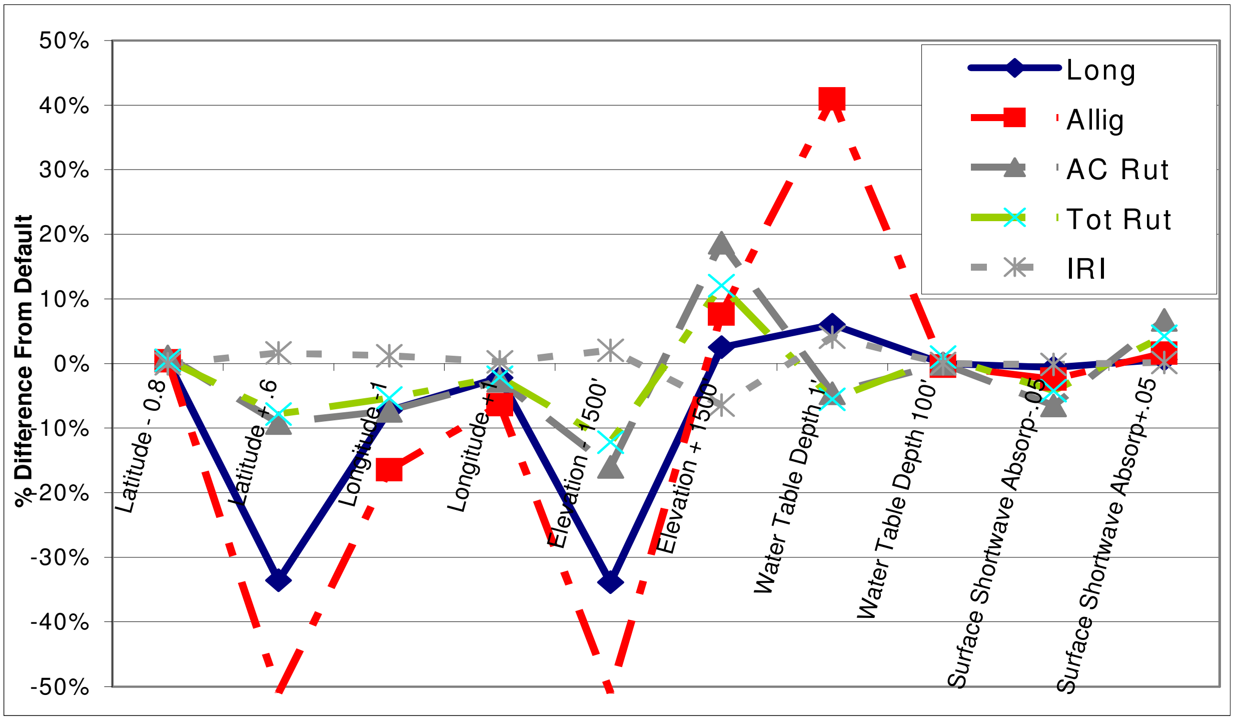

Figure E-3. Dry-Cold, AC-Intermediate, Climate Variables.

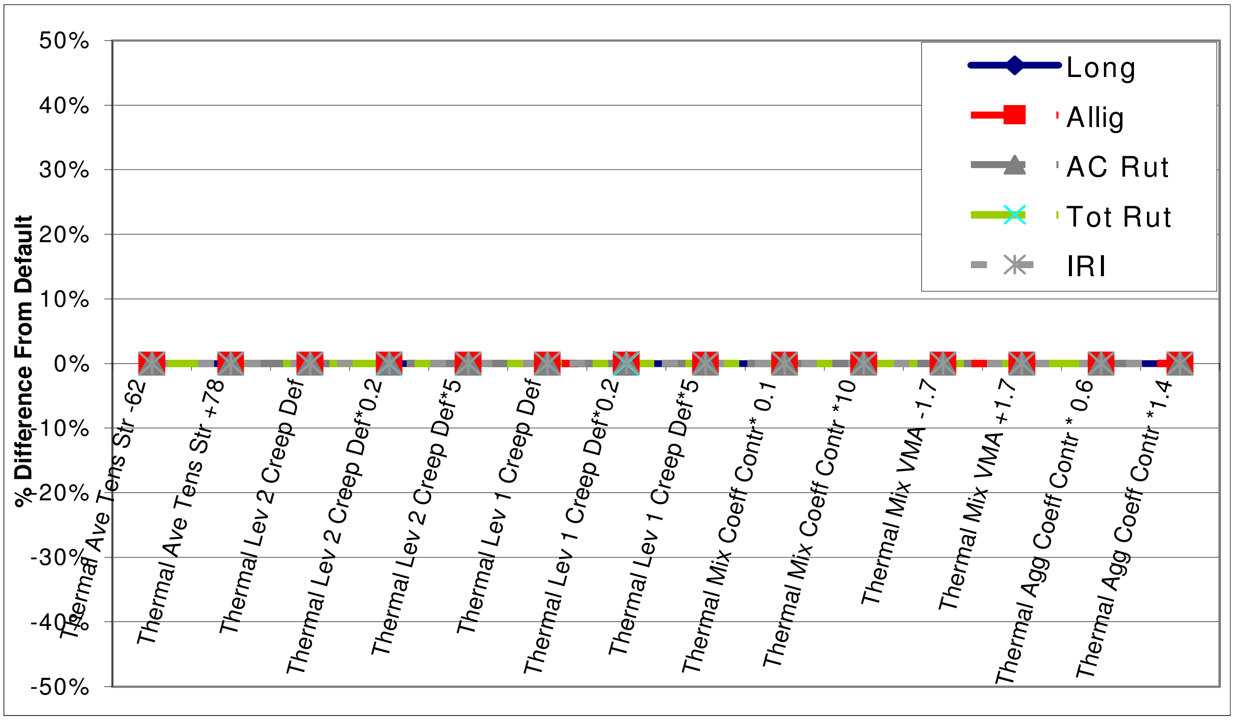

Figure E-4. Dry-Cold, AC-Intermediate, Thermal Variables.

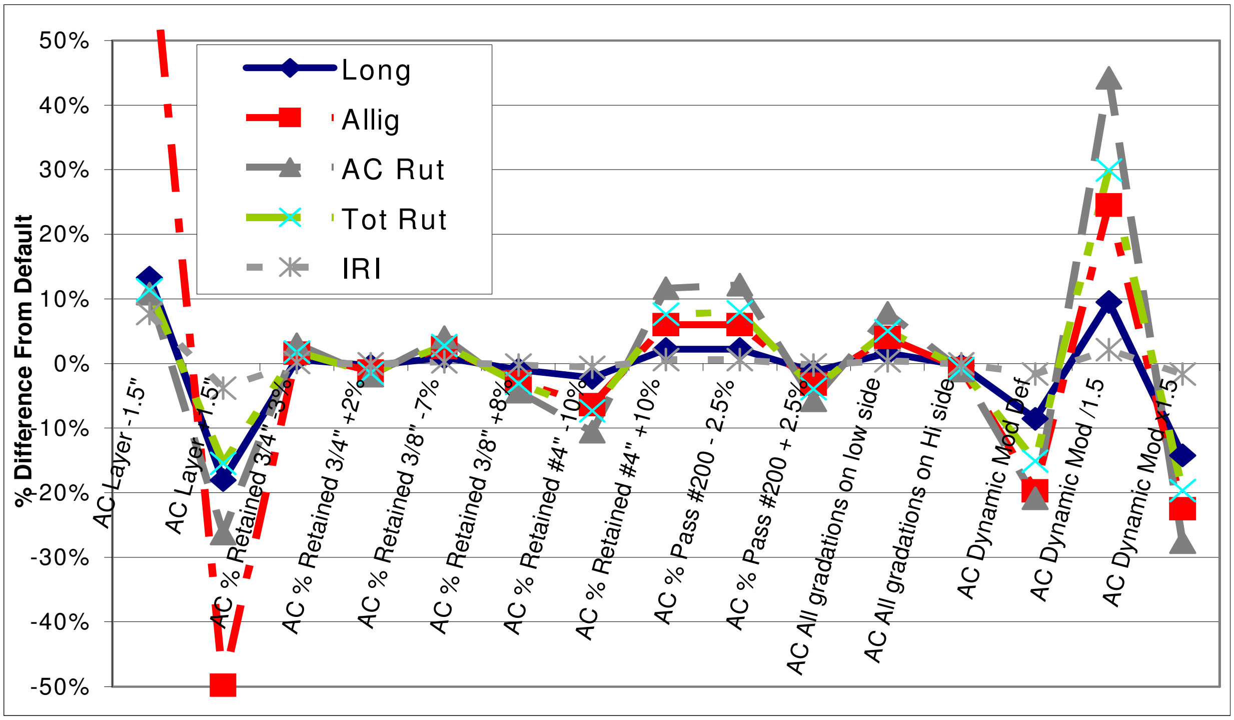

Figure E-5. Dry-Cold, AC-Intermediate, AC Mix Variables.

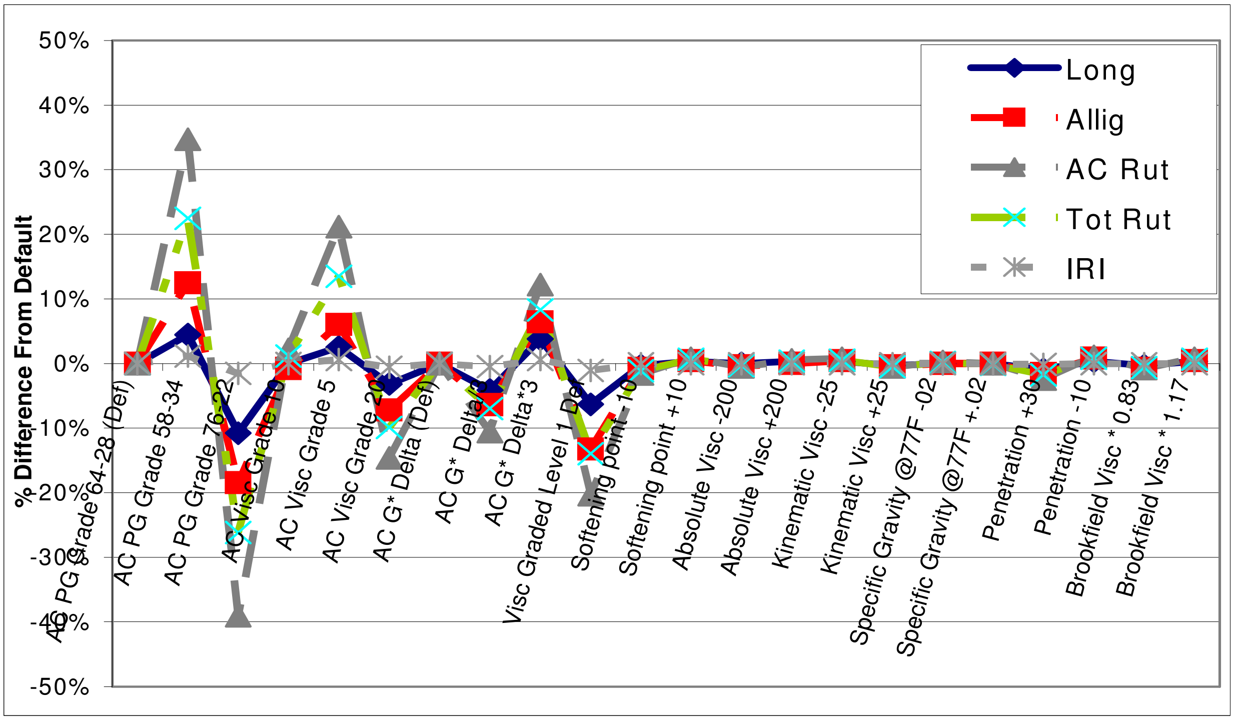

Figure E-6. Dry-Cold, AC-Intermediate, AC Binder Variables.

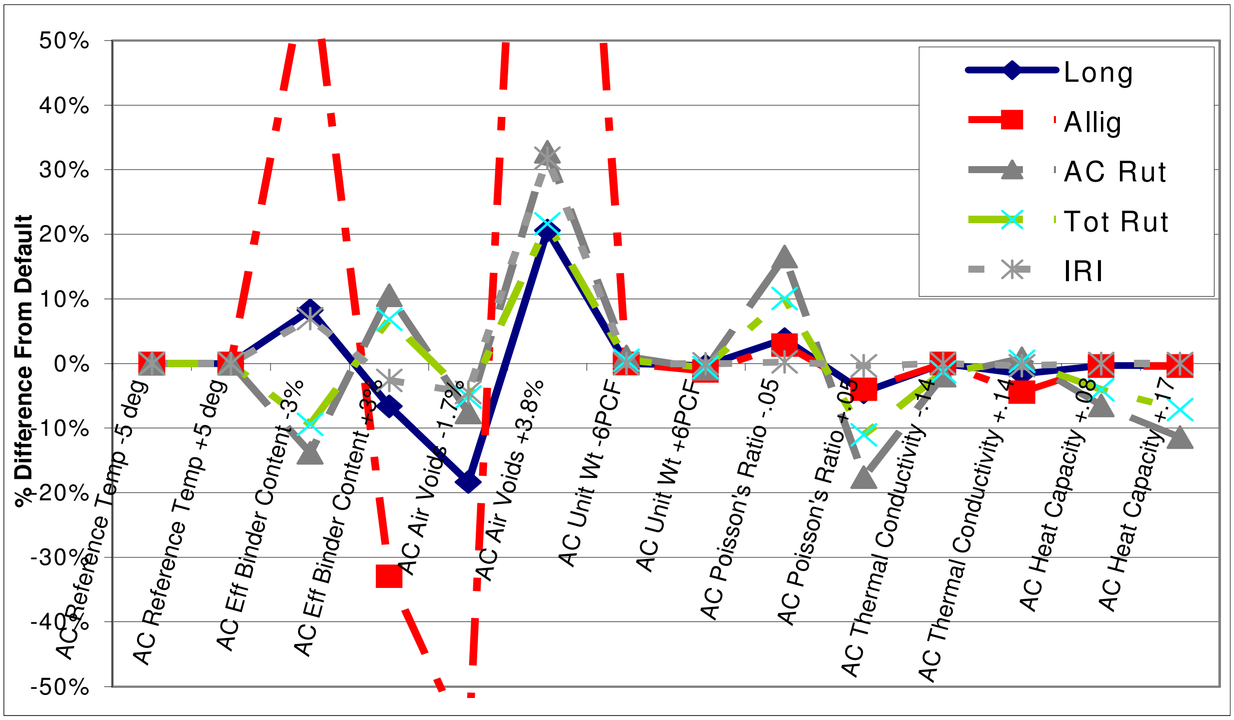

Figure E-7. Dry-Cold, AC-Intermediate, AC General Variables.

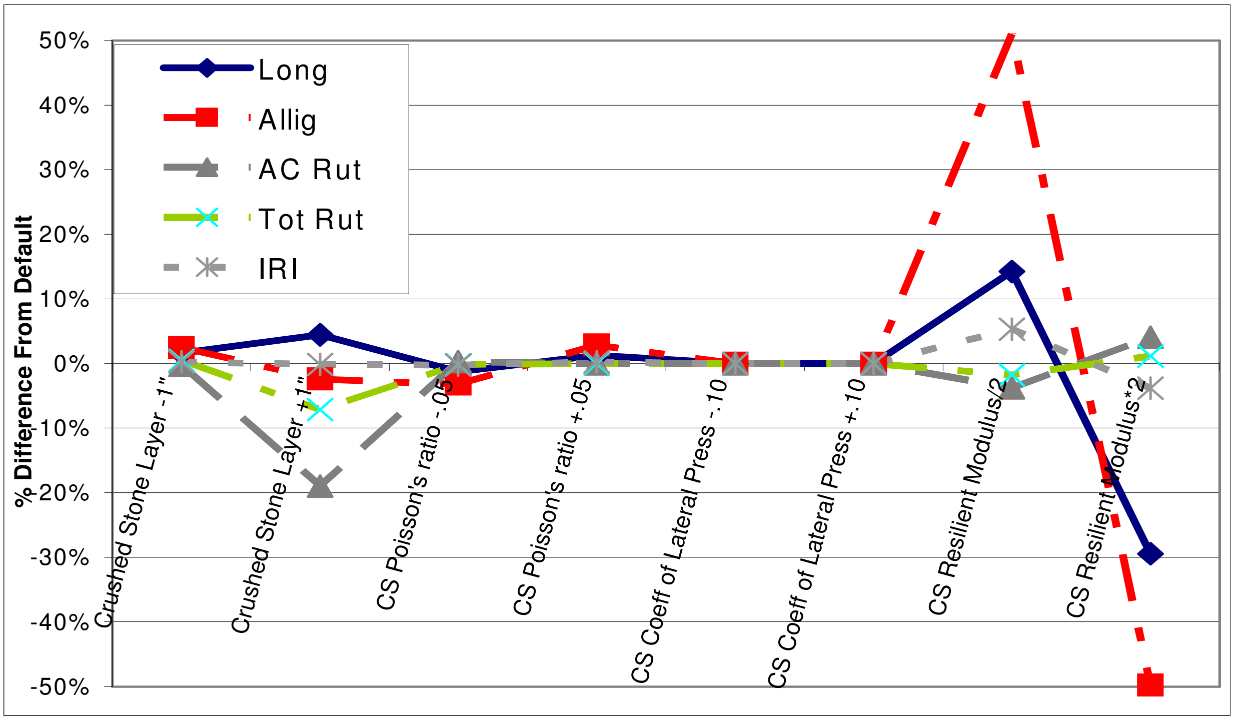

Figure E-8. Dry-Cold, AC-Intermediate, Crushed Stone Structural Variables.

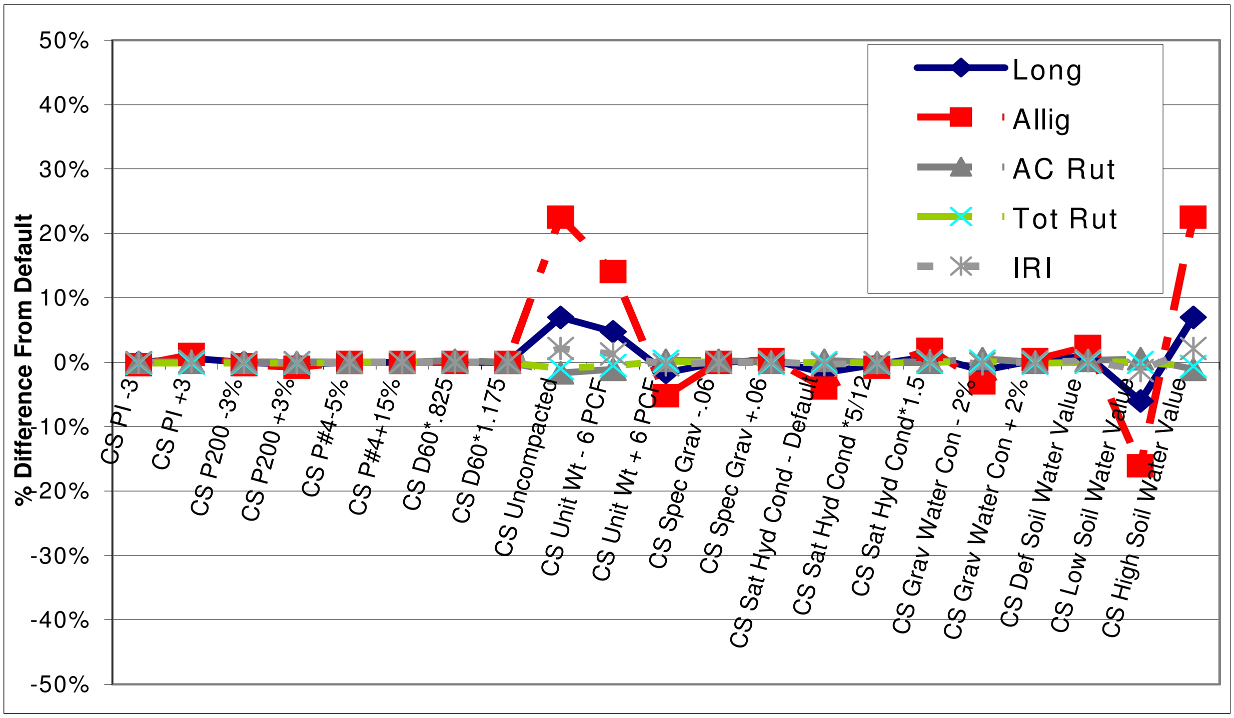

Figure E-9. Dry-Cold, AC-Intermediate, Crushed Stone Climatic Variables.

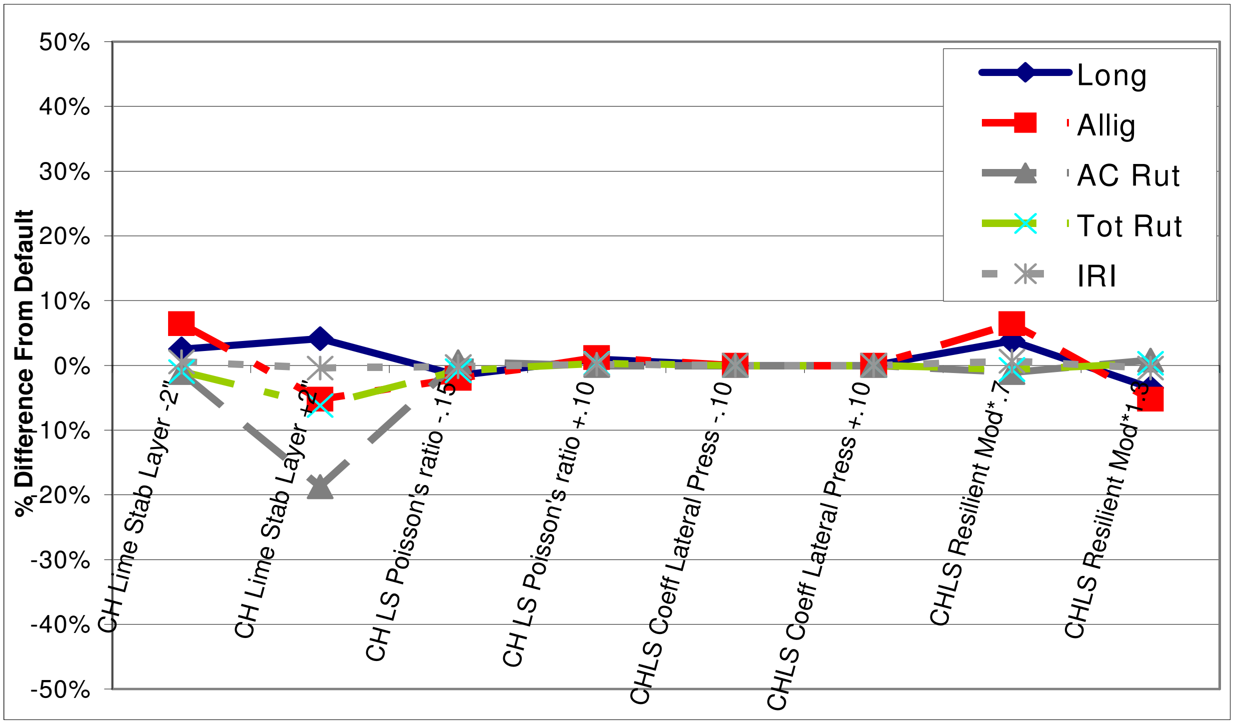

Figure E-10. Dry-Cold, AC-Intermediate, Lime Treated Structural Variables.

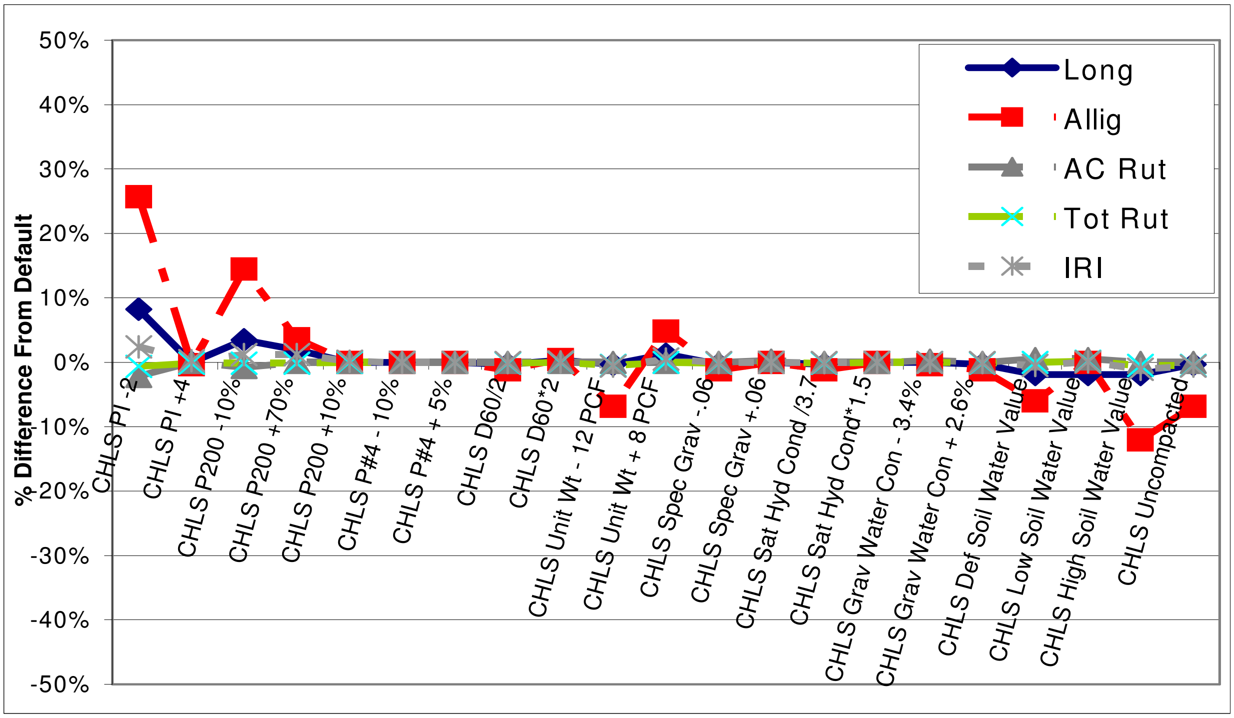

Figure E-11. Dry-Cold, AC-Intermediate, Lime Treated Climatic Variables.

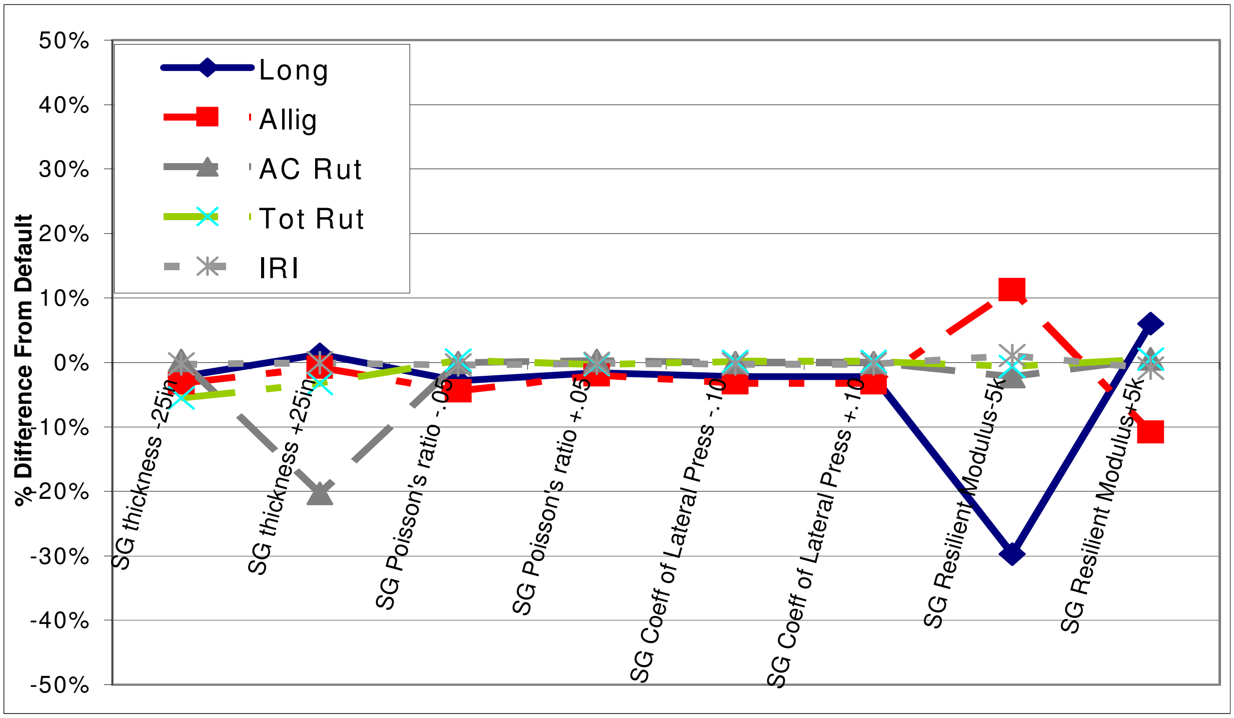

Figure E-12. Dry-Cold, AC-Intermediate, Subgrade Structural Variables.

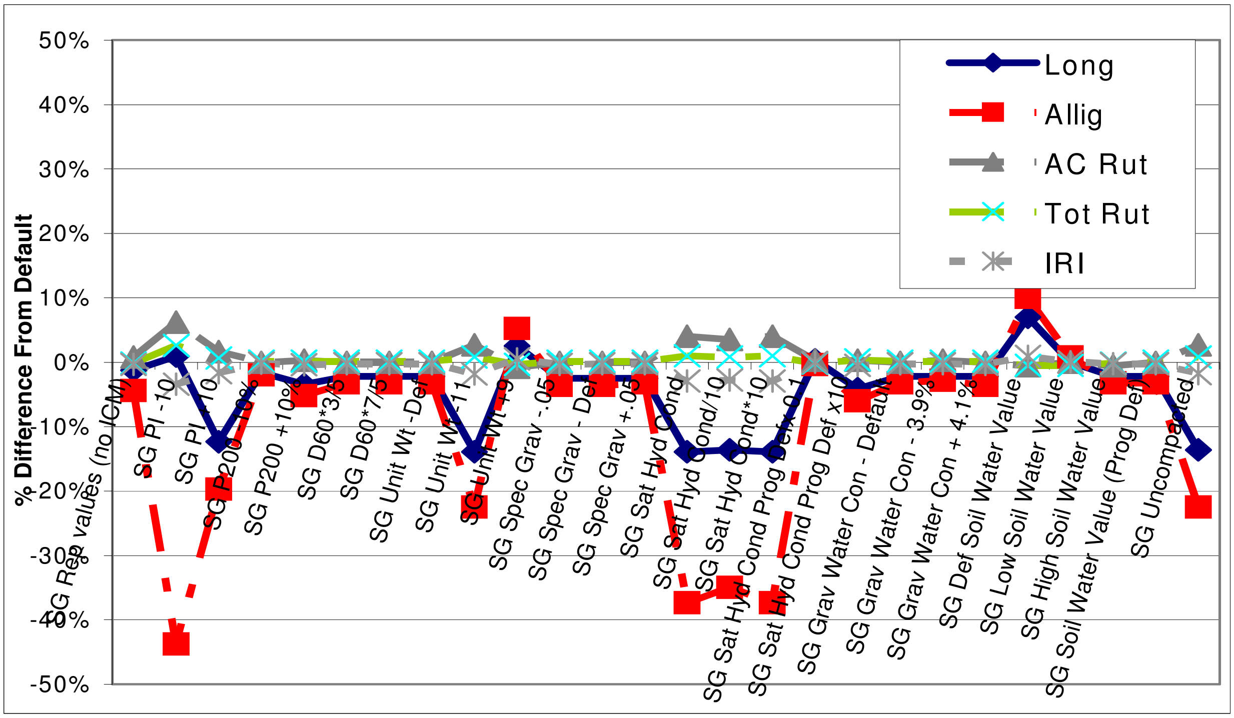

Figure E-13. Dry-Cold, AC-Intermediate, Subgrade Climatic Variables.

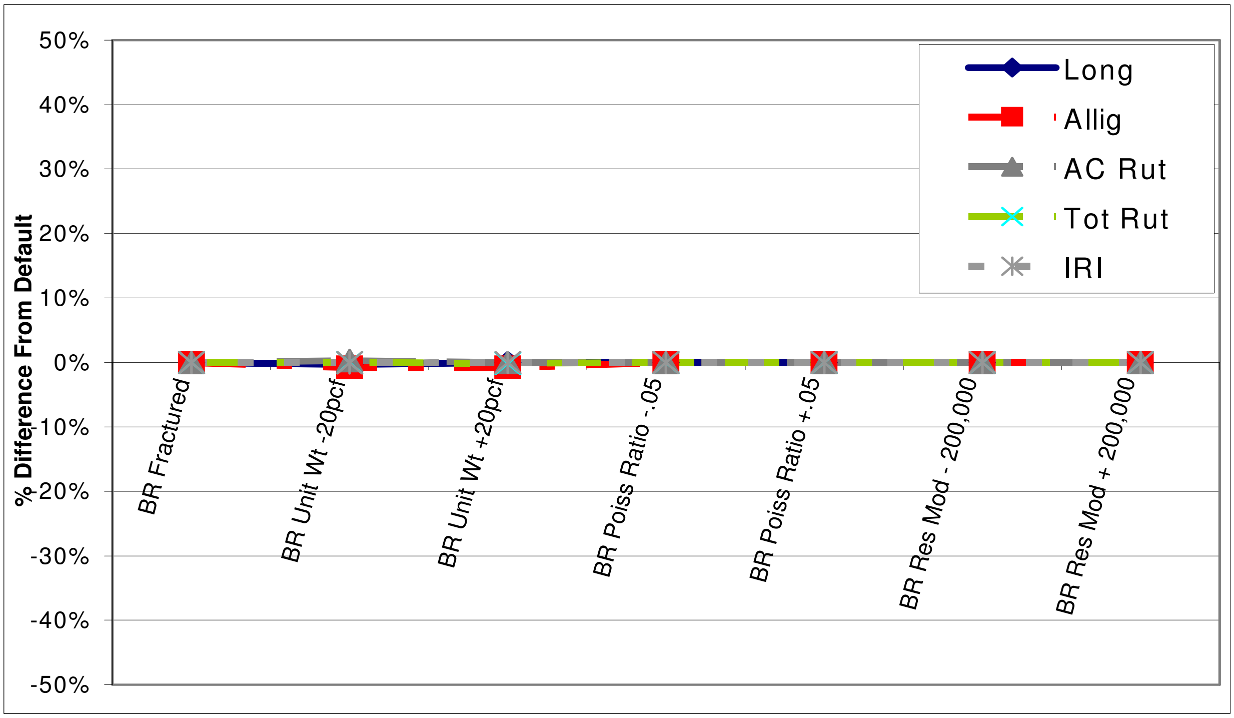

Figure E-14. Dry-Cold, AC-Intermediate, Bedrock Variables.

Table E-11. Results of Dry-Cold, AC-Intermediate, General Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
Base Construction −2 month	<<<	<<<	>	<	<<<
Base Construction +2 month	=	=	>	=	<
Construction +2 month (Hot)	=	=	<	<	=
Construction +4 month (Cold)	=	=	=	<	=
Construction −5 month (Cold)	<<<	<<<	>	<	<<
Traffic +4 month (More Cure)	=	<	<	<	=
Traffic −1 month (Less Cure)	=	=	=	<	=
Initial IRI +12	=	=	=	=	>>>
Initial IRI −13	=	=	=	=	<<<
Local Road TTC Class 9	<<<	<<	<<	<<<	<<
Minor Arterial TTC Class 4	<<<	<<	<<	<<	<<

Table E-12. Results of Dry-Cold, AC-Intermediate, Traffic Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
AADT −193 (20%)	<<	<<	<<	<<	<<
AADT +232 (20%)	>>	>>	>>	>>	>>
Lane Width 2' Less	=	=	=	=	=
Lane Width 2' More	=	=	=	=	=
Wander 2" Less	>>	>>	>>	>>	>>
Wander 2" More	<<	<<	<	<<	<<
Wheel Loca 4" Close to Ln Mrk	=	=	=	=	=
Wheel Loca 4" Far to Ln Mrk	=	=	=	=	=
All Tire Press +30 psi	<	>	>>>	>>>	>>
All Tire Press −30 psi	<<	<<	<<<	<<<	<<
Dual Tire Press +30 psi	<	>	>>>	>>>	>>
Dual Tire Press −30 psi	<<	<<	<<<	<<<	<<
Single Tire Press +30 psi	=	=	=	=	=
Single Tire Press −30 psi	=	=	=	=	=

Table E-13. Results of Dry-Cold, AC-Intermediate, Climate Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
Elevation 1500'	< < <	< < <	< < <	< < <	> >
Elevation +1500'	> >	> >	> > >	> > >	< < <
Latitude −0.8	>	>	>	>	<
Latitude +0.6	< < <	< < <	< <	< <	> >
Longitude +1	< <	< <	<	<	>
Longitude −1	< < <	< <	< <	< <	> >
Water Table Depth 1'	> > >	> > >	< <	< <	> > >
Water Table Depth 100'	=	<	=	>	=
Surface Shortwave Absorp −0.05	<	<	< <	< <	<
Surface Shortwave Absorp +0.05	>	>	> >	> >	>

Table E-14. Results of Dry-Cold, AC-Intermediate, AC Thermal Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
Thermal Agg Coeff Contr×0.6	=	=	=	=	=
Thermal Agg Coeff Contr×0.4	=	=	=	=	=
Thermal Ave Tens Str +78	=	=	=	=	=
Thermal Ave Tens Str −62	=	=	=	=	=
Thermal Lev 1 Creep Def	=	=	=	=	=
Thermal Lev 1 Creep Def×0.2	=	=	=	=	>
Thermal Lev 1 Creep Def×5	=	=	=	=	=
Thermal Lev 2 Creep Def	=	=	=	=	=
Thermal Lev 2 Creep Def×0.2	=	=	=	=	>
Thermal Lev 2 Creep Def×5	=	=	=	=	=
Thermal Mix Coeff Contr×10	=	=	=	=	=
Thermal Mix Coeff Contr×0.1	=	=	=	=	=
Thermal Mix VMA +1.7%	=	=	=	=	=
Thermal Mix VMA −1.7%	=	=	=	=	=

Table E-15. Results of Dry-Cold, AC-Intermediate, AC Binder Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
AC Layer +1.5"	< < <	< < <	< < <	< < <	< < <
AC Layer −1.5"	> > >	> > >	> >	> >	> > >
Absolute Visc +200	>	=	>	>	=
Absolute Visc −200	=	<	<	<	<
Brookfield Visc×0.83	<	<	<	<	<
Brookfield Visc×1.17	>	>	>	>	=
Kinematic Visc +25	<	<	<	<	<
Kinematic Visc −25	>	>	>	>	=
Penetration +30	<	<	<	<	<
Penetration −10	>	>	>	>	=
Softening Point +10	>	>	>	>	=
Softening Point −10	<	<	<	<	<
Specific Gravity @77 °F + 0.02	=	=	=	<	<
Specific Gravity @77 °F - 0.02	=	=	>	>	=
Visc Graded Level 1 Def	< < <	< <	< < <	< < <	< <
AC Visc Grade 10	=	<	>	>	=
AC Visc Grade 20	< <	< <	< <	< <	< <
AC Visc Grade 5	> >	> >	> > >	> > >	> >
AC G* Delta (Def)	=	=	=	=	=
AC G* Delta×3	> >	> >	> >	> >	> >
AC G* Delta/3	< <	< <	< <	< <	< <
AC PG Grade 58-34	> >	> >	> > >	> > >	> >
AC PG Grade 64-28 (Def)	=	=	=	=	=
AC PG Grade 76-22	< < <	< <	< < <	< < <	< <

Table E-16. Results of Dry-Cold, AC-Intermediate, General AC Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
AC Air Voids +3.8%	> > >	> > >	> > >	> > >	> > >
AC Air Voids −1.7%	< < <	< < <	< <	< <	< < <
AC Eff Binder Content +3%	< < <	< < <	> >	> >	< < <
AC Eff Binder Content −3%	> > >	> > >	< <	< <	> > >
AC Heat Capacity +0.08	<	<	< <	< <	=
AC Heat Capacity +0.17	<	<	< <	< <	=
AC Poisson’s Ratio −0.05	> >	>	> > >	> >	>
AC Poisson’s Ratio +0.05	< <	<	< < <	< <	<
AC Reference Temp +5 °F	=	=	=	=	=
AC Reference Temp −5 °F	=	=	=	=	=
AC Thermal Conductivity −0.14	=	=	<	<	=
AC Thermal Conductivity +0.14	< <	<	>	>	<
AC Unit Wt +6 pcf	<	<	<	<	<
AC Unit Wt −6 pcf	=	=	>	>	=

Table E-17. Results of Dry-Cold, AC-Intermediate, AC Mix Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
AC % Pass #200 −2.5%	> >	> >	> >	> >	> >
AC % Pass #200 +2.5%	< <	<	< <	< <	<
AC % Retained #4 +10%	> >	> >	> >	> >	> >
AC % Retained #4 −10%	< <	< <	< <	< <	< <
AC % Retained 3/4" +2%	<	<	<	<	<
AC % Retained 3/4" −3%	>	>	>	>	>
AC % Retained 3/8" +8%	<	<	< <	< <	<
AC % Retained 3/8" −7%	>	>	> >	> >	>
AC All Gradations on Hi Side	<	<	<	<	<
AC All Gradations on Low Side	> >	>	> >	> >	>
AC Dynamic Mod/1.5	> > >	> >	> > >	> > >	> >
AC Dynamic Mod Def	< < <	< <	< < <	< < <	< <
AC Dynamic Mod×1.5	< < <	< <	< < <	< < <	< <

Table E-18. Results of Dry-Cold, AC-Intermediate, Crushed Stone ICM Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
CS D60×0.825	=	=	>	=	=
CS D60×1.175	=	=	=	=	=
CS Def Soil Water Value	>	>	>	=	>
CS Grav Water Con −2%	< <	<	>	>	<
CS Grav Water Con - Def	=	=	=	<	=
CS Grav Water Con +2%	>	>	=	<	>
CS High Soil Water Value	> > >	> >	<	<	> >
CS Low Soil Water Value	< < <	< <	>	=	< <
CS P#4 +15%	=	=	=	=	=
CS P#4 −5%	=	=	=	=	=
CS P200 +3%	<	<	=	<	<
CS P200 −3%	=	<	=	<	=
CS PI +3	>	>	=	<	>
CS PI −3	=	<	=	<	=
CS Sat Hyd Cond - Default	< <	<	>	=	<
CS Sat Hyd Cond×5/12	<	<	=	<	<
CS Sat Hyd Cond Prog Def)	=	=	=	=	=
CS Sat Hyd Cond×1.5	>	>	=	=	>
CS Soil Water Value (Prog Def)	=	=	=	=	=
CS Spec Grav - Default	=	=	=	<	=
CS Spec Grav −0.06	=	=	>	=	=
CS Spec Grav +0.06	>	>	=	<	>
CS Uncompacted	> > >	> >	<	<	> >
CS Unit Wt −6 pcf	> >	> >	<	<	> >
CS Unit Wt - Default	=	=	=	=	=
CS Unit Wt +6 pcf	< <	<	>	>	<

Table E-19. Results of Dry-Cold, AC-Intermediate, Crushed Stone Strength Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
Crushed Stone Layer +1"	> >	<	< < <	< <	<
Crushed Stone Layer −1"	> >	>	<	>	>
CS Coeff of Lateral Press −0.10	=	=	=	=	=
CS Coeff of Lateral Press +0.10	=	=	=	=	=
CS Poisson’s Ratio −0.05	< <	<	>	<	<
CS Poisson’s Ratio +0.05	> >	>	=	=	>
CS Resilient Modulus×2	< < <	< < <	> >	>	< < <
CS Resilient Modulus/2	> > >	> > >	< <	<	> > >

Table E-20. Results of Dry-Cold, AC-Intermediate, Crushed Stone ICM Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
CHLS D60×2	>	>	=	=	>
CHLS D60/2	<	<	=	<	<
CHLS Def Soil Water Value	< <	< <	>	=	< <
CHLS Grav Water Con −3.4%	=	<	>	=	=
CHLS Grav Water Con +2.6%	<	<	=	<	<
CHLS Grav Water Con - Def	=	=	=	=	=
CHLS High Soil Water Value	< <	< <	=	<	< <
CHLS Low Soil Water Value	< <	=	>	>	>
CHLS P#4 −10%	=	=	=	=	=
CHLS P#4 +5%	=	=	=	=	=
CHLS P200 +10%	=	=	=	=	>
CHLS P200 +70%	> >	>	=	<	> >
CHLS P200 −10%	> >	> >	<	<	> >
CHLS PI +4	=	<	=	<	>
CHLS PI −2	> > >	> >	<	<	> >
CHLS Sat Hyd Cond - Def	=	=	=	=	=
CHLS Sat Hyd Cond/3.7	<	<	=	<	<
CHLS Sat Hyd Cond×1.5	=	=	=	=	=
CHLS Soil Water Value (Prog Def)	=	=	=	=	=
CHLS Spec Grav - Def	=	<	=	=	=
CHLS Spec Grav −0.06	<	<	=	<	<
CHLS Spec Grav +0.06	=	=	>	=	=
CHLS Uncompacted	<	< <	=	<	< <
CHLS Unit Wt −12 pcf	<	< <	=	<	< <
CHLS Unit Wt - Default	=	=	=	=	=
CHLS Unit Wt +8 pcf	> >	>	=	=	> >

Table E-21. Results of Dry-Cold, AC-Intermediate, Lime Treated Strength Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
CH Lime Stab Layer +2"	>>	<	<<<	<<	<
CH Lime Stab Layer −2"	>>	>>	<	<	>>
CH LS Poisson’s Ratio −0.15	<<	<	>	<	<
CH LS Poisson’s Ratio +0.10	>	>	=	>	>
CHLS Coeff Lateral Press −0.10	=	=	=	=	=
CHLS Coeff Lateral Press +0.10	=	=	=	=	=
CHLS Resilient Mod×0.7	>>	>>	<	<	>>
CHLS Resilient Mod×1.3	<<	<	>	>	<

Table E-22. Results of Dry-Cold, AC-Intermediate, Subgrade ICM Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
SG D60×3/5	<<	<	=	>	<
SG D60×7/5	<<	<	=	>	<
SG Def Soil Water Value	>>>	>>	<	<	>>
SG Grav Water Con −3.9%	<<	<	>	>	<
SG Grav Water Con - Default	<<	<	=	>	<
SG Grav Water Con +4.1%	<<	<	=	>	<
SG High Soil Water Value	<<	<	<	<	<
SG Low Soil Water Value	=	>	=	<	>
SG P200 +10%	<<	<	>	>	<
SG P200 −10%	<<	<	=	>	<
SG PI +10	<<<	<<	>	>	<<
SG PI −10	>	<<<	>>	>>	<<<
SG Rep Values (no ICM)	<<	<	>	<	<
SG Sat Hyd Cond	<<<	<<<	>>	>	<<<
SG Sat Hyd Cond (Prog Def)	=	=	=	=	=
SG Sat Hyd Cond Prog Def×10	<<	<<	>	>	<<
SG Sat Hyd Cond Prog Def×0.1	>	<	>	<	=
SG Sat Hyd Cond×10	<<<	<<<	>>	>	<<<
SG Sat Hyd Cond/10	<<<	<<<	>>	>	<<<
SG Soil Water Value (Prog Def)	<<	<	=	>	<
SG Spec Grav - Def	<<	<	=	>	<
SG Spec Grav −0.05	<<	<	=	>	<
SG Spec Grav +0.05	<<	<	=	>	<
SG Uncompacted	<<<	<<	>	>	<<
SG Unit Wt +9 pcf	>>	>	<	<	>>
SG Unit Wt −11 pcf	<<<	<<	>	>	<<
SG Unit Wt - Def	<<	<	=	>	<

Table E-23. Results of Dry-Cold, AC-Intermediate, Subgrade Strength Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
SG Coeff of Lateral Press −0.10	< <	<	=	>	<
SG Coeff of Lateral Press +0.10	< <	<	=	>	<
SG Poisson’s Ratio −0.05	< <	<	=	>	<
SG Poisson’s Ratio +0.05	< <	<	>	<	<
SG Resilient Modulus +5 ksi	> > >	< <	>	>	< <
SG Resilient Modulus −5 ksi	< < <	> >	<	<	> >
SG Thickness +25"	> >	<	< < <	< <	<
SG Thickness −25"	< <	<	>	< <	<

Table E-24. Results of Dry-Cold, AC-Intermediate, Bedrock Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
BR Fractured	=	=	=	=	=
BR Poiss Ratio −0.05	=	=	=	=	=
BR Poiss Ratio +0.05	=	=	=	=	=
BR Res Mod −200,000	=	=	=	=	=
BR Res Mod +200,000	=	=	=	=	=
BR Unit Wt +20 pcf	=	<	=	<	=
BR Unit Wt −20 pcf	<	<	>	=	<

APPENDIX F

WET-WARM, AC INTERMEDIATE RESULTS

Table F-1. Wet-Warm, AC-Intermediate, Highly Significant Variables - Longitudinal Cracking.

Description	Category	Long-Rank
Local Road TTC Class 9	02-Site	0.2
Minor Arterial TTC Class 4	02-Site	0.3
Water Table Depth 1'	04-Climate	0.2
Water Table Depth at 6'	04-Climate	0.5
AC Layer +1.5"	07-AC	0.2
AC Layer −1.5"	07-AC	0.1
AC Visc Grade 30	07-AC-Binder-AC-3	0.5
AC G* Delta×3	07-AC-Binder-SP-1	0.2
AC PG Grade 76-22	07-AC-Binder-SP-3	0.3
AC PG Grade 82-28	07-AC-Binder-SP-3	0.2
AC Air Voids +3.8%	07-AC-General	0.1
AC Air Voids −1.7%	07-AC-General	0.2
AC Eff Binder Cont +3%	07-AC-General	0.5
AC Eff Binder Cont −3%	07-AC-General	0.3
AC Poisson’s Ratio +0.05	07-AC-General	0.5
AC Dynamic Mod ×1.5	07-AC-Mix	0.2
AC Dynamic Mod/1.5	07-AC-Mix	0.3
CS High Soil Water Value	08-CS-ICM	0.2
CS Low Soil Water Value	08-CS-ICM	0.4
CS Uncompacted	08-CS-ICM	0.2
CS Unit Wt −6 pcf	08-CS-ICM	0.4
Crushed Stone Layer +1"	08-CS-Str	0.3
CS Resilient Mod×2	08-CS-Str	0.1
CS Resilient Mod/2	08-CS-Str	0.1
CHLS P200 +70%	09-CHLS-ICM	0.4
CHLS P200 −10%	09-CHLS-ICM	0.2
CHLS PI −2	09-CHLS-ICM	0.2
CH Lime Stab Layer +2"	09-CHLS-Str	0.3
CH Lime Stab Layer −2"	09-CHLS-Str	0.4
CHLS Resilient Mod×0.7	09-CHLS-Str	0.5
SG Def Soil Water Value	10-SG-ICM	0.2
SG P200 −10%	10-SG-ICM	0.5
SG PI +10	10-SG-ICM	0.5
SG PI −10	10-SG-ICM	0.3
SG Rep (no ICM)	10-SG-ICM	0.5
SG Sat Hyd Cond×100	10-SG-ICM	0.5
SG Uncompacted	10-SG-ICM	0.2
SG Unit Wt +23.4 pcf	10-SG-ICM	0.2
SG Unit Wt −16.7 pcf	10-SG-ICM	0.2
SG Def Thick −25"	10-SG-Str	0.1
SG Resilient Mod +4 ksi	10-SG-Str	0.1
SG Resilient Mod −2 ksi	10-SG-Str	0.2
SG Thick +25"	10-SG-Str	0.2
BR Deleted	11-BR	0.4

Table F-2. Wet-Warm, AC-Intermediate, Significant Variables - Longitudinal Cracking.

Description	Category	Long-Rank
AADT −193 (20%)	03-Traffic	1.0
AADT +232 (20%)	03-Traffic	1.0
Wander 2" Less	03-Traffic-General	1.2
Wander 2" More	03-Traffic-General	1.3
All Tire Press −30 psi	03-Traffic-General-Axle	1.3
Dual Tire Press −30 psi	03-Traffic-General-Axle	1.3
Water Table Depth at 2'	04-Climate	0.6
Penetration +10	07-AC-Binder-AC-1	2.4
Visc Graded Level 1 Def	07-AC-Binder-AC-1	0.6
AC Visc Grade 20	07-AC-Binder-AC-3	0.9
AC G* Delta/3	07-AC-Binder-SP-1	1.2
AC PG Grade 58-34	07-AC-Binder-SP-3	0.6
AC PG Grade 70-22	07-AC-Binder-SP-3	0.8
AC Poisson’s Ratio −0.05	07-AC-General	0.6
AC % Pass #200 −2.5%	07-AC-Mix	1.2
AC % Pass #200 +2.5%	07-AC-Mix	1.9
AC % Retained #4 +10%	07-AC-Mix	1.2
AC % Retained #4 −10%	07-AC-Mix	1.0
AC % Retained 3/8" +8%	07-AC-Mix	2.4
AC All Gradations on Low Side	07-AC-Mix	1.7
AC Dynamic Mod Def	07-AC-Mix	1.7
CS Unit Wt +6 pcf	08-CS-ICM	1.5
Crushed Stone Layer −1"	08-CS-Str	0.9
CS Poisson’s Ratio −0.05	08-CS-Str	1.6
CS Poisson’s Ratio +0.05	08-CS-Str	1.9
CHLS D60×2	09-CHLS-ICM	1.7
CHLS D60/4	09-CHLS-ICM	1.7
CHLS Def Soil Water Value	09-CHLS-ICM	1.0
CHLS Grav Water Con −3.2%	09-CHLS-ICM	1.5
CHLS High Soil Water Value	09-CHLS-ICM	1.0
CHLS Low Soil Water Value	09-CHLS-ICM	1.3
CHLS Sat Hyd Cond/3.7	09-CHLS-ICM	2.4
CHLS Uncompacted	09-CHLS-ICM	1.6
CHLS Unit Wt −12 pcf	09-CHLS-ICM	1.6
CHLS Unit Wt +8 pcf	09-CHLS-ICM	1.0
CH LS Poisson’s Ratio - 0.15	09-CHLS-Str	1.7
CHLS Resilient Mod×1.3	09-CHLS-Str	0.6
SG P200 +10%	10-SG-ICM	0.8

Table F-3. Wet-Warm, AC-Intermediate, Highly Significant Variables - Alligator Cracking.

Description	Category	Allig-Rank
Water Table Depth 1'	04-Climate	0.3
Water Table Depth at 2'	04-Climate	0.4
Water Table Depth at 4'	04-Climate	0.5
AC Layer +1.5"	07-AC	0.3
AC Layer −1.5"	07-AC	0.2
AC G* Delta×3	07-AC-Binder-SP-1	0.4
AC Air Voids +3.8%	07-AC-General	0.1
AC Air Voids −1.7%	07-AC-General	0.3
AC Eff Binder Cont +3%	07-AC-General	0.4
AC Eff Binder Cont −3%	07-AC-General	0.2
CS High Soil Water Value	08-CS-ICM	0.4
CS Uncompacted	08-CS-ICM	0.5
CS Resilient Mod×2	08-CS-Str	0.3
CS Resilient Mod/2	08-CS-Str	0.3
CHLS P200 −10%	09-CHLS-ICM	0.5
CHLS PI −2	09-CHLS-ICM	0.4
SG Def Soil Water Value	10-SG-ICM	0.5
SG Def Thick −25"	10-SG-Str	0.5

Table F-4. Wet-Warm, AC-Intermediate, Significant Variables - Alligator Cracking.

Description	Category	Allig-Rank
Local Road TTC Class 9	02-Site	0.6
Minor Arterial TTC Class 4	02-Site	1.1
AADT −193 (20%)	03-Traffic	1.1
AADT +232 (20%)	03-Traffic	0.9
Wander 2" Less	03-Traffic-General	1.3
Wander 2" More	03-Traffic-General	1.5
All Tire Press −30 psi	03-Traffic-General-Axle	1.2
Dual Tire Press −30 psi	03-Traffic-General-Axle	1.2
AC Visc Grade 30	07-AC-Binder-AC-3	1.6
AC PG Grade 58-34	07-AC-Binder-SP-3	1.9
AC PG Grade 76-22	07-AC-Binder-SP-3	0.9
AC PG Grade 82-28	07-AC-Binder-SP-3	0.9
AC Dynamic Mod ×1.5	07-AC-Mix	0.7
AC Dynamic Mod/1.5	07-AC-Mix	0.8
CS Low Soil Water Value	08-CS-ICM	0.8
CS Unit Wt −6 pcf	08-CS-ICM	0.9
Crushed Stone Layer −1"	08-CS-Str	2.5
CHLS Low Soil Water Value	09-CHLS-ICM	1.9
CHLS P200 +70%	09-CHLS-ICM	1.1
CHLS Uncompacted	09-CHLS-ICM	2.0
CHLS Unit Wt −12 pcf	09-CHLS-ICM	2.0
CHLS Unit Wt +8 pcf	09-CHLS-ICM	2.1
CH Lime Stab Layer +2"	09-CHLS-Str	1.3
CH Lime Stab Layer −2"	09-CHLS-Str	1.0
CHLS Resilient Mod×0.7	09-CHLS-Str	1.9
CHLS Resilient Mod×1.3	09-CHLS-Str	2.4
SG P200 −10%	10-SG-ICM	2.4
SG PI −10	10-SG-ICM	1.2
SG Sat Hyd Cond×100	10-SG-ICM	1.9
SG Uncompacted	10-SG-ICM	1.3
SG Unit Wt +23.4 pcf	10-SG-ICM	0.7
SG Unit Wt −16.7 pcf	10-SG-ICM	1.1
SG Resilient Mod +4 ksi	10-SG-Str	2.2
SG Resilient Mod −2 ksi	10-SG-Str	2.5
BR Deleted	11-BR	1.1

Table F-5. Wet-Warm, AC-Intermediate, Highly Significant Variables - AC Rutting.

Description	Category	ACRut-rank
All Tire Press +30 psi	03-Traffic-General-Axle	0.3
All Tire Press −30 psi	03-Traffic-General-Axle	0.2
Dual Tire Press +30 psi	03-Traffic-General-Axle	0.3
Dual Tire Press −30 psi	03-Traffic-General-Axle	0.2
AC Layer +1.5"	07-AC	0.3
Visc Graded Level 1 Def	07-AC-Binder-AC-1	0.4
AC Visc Grade 30	07-AC-Binder-AC-3	0.4
AC G* Delta×3	07-AC-Binder-SP-1	0.4
AC PG Grade 58-34	07-AC-Binder-SP-3	0.3
AC PG Grade 70-22	07-AC-Binder-SP-3	0.5
AC PG Grade 76-22	07-AC-Binder-SP-3	0.2
AC PG Grade 82-28	07-AC-Binder-SP-3	0.2
AC Air Voids +3.8%	07-AC-General	0.3
AC Poisson’s Ratio −0.05	07-AC-General	0.5
AC Poisson’s Ratio +0.05	07-AC-General	0.5
AC Dynamic Mod ×1.5	07-AC-Mix	0.2
AC Dynamic Mod/1.5	07-AC-Mix	0.2
Crushed Stone Layer +1"	08-CS-Str	0.4
CH Lime Stab Layer +2"	09-CHLS-Str	0.4
SG Thick +25"	10-SG-Str	0.4

Table F-6. Wet-Warm, AC-Intermediate, Significant Variables - AC Rutting.

Description	Category	ACRut-Rank
Local Road TTC Class 9	02-Site	0.7
Minor Arterial TTC Class 4	02-Site	2.2
AADT −193 (20%)	03-Traffic	1.0
AADT +232 (20%)	03-Traffic	1.0
Wander 2" Less	03-Traffic-General	1.6
Water Table Depth 1'	04-Climate	1.4
Water Table Depth at 2'	04-Climate	1.8
Water Table Depth at 4'	04-Climate	2.2
Surface Shortwave Absorp −0.05	06-Drain	1.2
Surface Shortwave Absorp +0.05	06-Drain	1.3
AC Layer −1.5"	07-AC	0.9
AC Visc Grade 20	07-AC-Binder-AC-3	0.7
AC G* Delta/3	07-AC-Binder-SP-1	1.1
AC Air Voids −1.7%	07-AC-General	1.1
AC Eff Binder Cont +3%	07-AC-General	0.9
AC Eff Binder Cont −3%	07-AC-General	0.6
AC Heat Capacity +0.08	07-AC-General	1.8
AC Heat Capacity +0.17	07-AC-General	1.1
AC % Pass #200 −2.5%	07-AC-Mix	0.7
AC % Pass #200 +2.5%	07-AC-Mix	1.5
AC % Retained #4 +10%	07-AC-Mix	0.8
AC % Retained #4 −10%	07-AC-Mix	0.8
AC % Retained 3/8" +8%	07-AC-Mix	2.0
AC % Retained 3/8" −7%	07-AC-Mix	2.1
AC All Gradations on Low Side	07-AC-Mix	1.2
CS Resilient Mod×2	08-CS-Str	2.4
CS Resilient Mod/2	08-CS-Str	2.1
SG Def Soil Water Value	10-SG-ICM	1.4

Table F-7. Wet-Warm, AC-Intermediate, Highly Significant Variables - Total Rutting Rank.

Description	Category	TotR-Rank
All Tire Press +30 psi	03-Traffic-General-Axle	0.4
All Tire Press −30 psi	03-Traffic-General-Axle	0.3
Dual Tire Press +30 psi	03-Traffic-General-Axle	0.4
Dual Tire Press −30 psi	03-Traffic-General-Axle	0.3
AC Layer +1.5"	07-AC	0.4
Visc Graded Level 1 Def	07-AC-Binder-AC-1	0.5
AC Visc Grade 30	07-AC-Binder-AC-3	0.5
AC G* Delta×3	07-AC-Binder-SP-1	0.4
AC PG Grade 58-34	07-AC-Binder-SP-3	0.3
AC PG Grade 76-22	07-AC-Binder-SP-3	0.3
AC PG Grade 82-28	07-AC-Binder-SP-3	0.3
AC Air Voids +3.8%	07-AC-General	0.3
AC Dynamic Mod ×1.5	07-AC-Mix	0.3
AC Dynamic Mod/1.5	07-AC-Mix	0.2
BR Deleted	11-BR	0.5

Table F-8. Wet-Warm, AC-Intermediate, Highly Significant Variables - Total Rutting Rank.

Description	Category	TotR-Rank
Local Road TTC Class 9	02-Site	0.6
Minor Arterial TTC Class 4	02-Site	1.3
AADT −193 (20%)	03-Traffic	1.0
AADT +232 (20%)	03-Traffic	1.0
Wander 2" Less	03-Traffic-General	1.7
Water Table Depth 1'	04-Climate	2.5
Surface Shortwave Absorp −0.05	06-Drain	1.5
Surface Shortwave Absorp +0.05	06-Drain	1.5
AC Layer −1.5"	07-AC	0.6
AC Visc Grade 20	07-AC-Binder-AC-3	0.8
AC G* Delta/3	07-AC-Binder-SP-1	1.3
AC PG Grade 70-22	07-AC-Binder-SP-3	0.6
AC Air Voids −1.7%	07-AC-General	1.3
AC Eff Binder Cont +3%	07-AC-General	1.0
AC Eff Binder Cont −3%	07-AC-General	0.7
AC Heat Capacity +0.08	07-AC-General	2.3
AC Heat Capacity +0.17	07-AC-General	1.4
AC Poisson's Ratio −0.05	07-AC-General	0.7
AC Poisson's Ratio +0.05	07-AC-General	0.6
AC % Pass #200 −2.5%	07-AC-Mix	0.8
AC % Pass #200 +2.5%	07-AC-Mix	1.7
AC % Retained #4 +10%	07-AC-Mix	0.9
AC % Retained #4 −10%	07-AC-Mix	1.0
AC % Retained 3/8" +8%	07-AC-Mix	2.3
AC % Retained 3/8" −7%	07-AC-Mix	2.4
AC All Gradations on Low Side	07-AC-Mix	1.3
Crushed Stone Layer +1"	08-CS-Str	0.8
CH Lime Stab Layer +2"	09-CHLS-Str	0.9
SG Thick +25"	10-SG-Str	1.7
SG Thick −25"	10-SG-Str	1.2

Table F-9. Wet-Warm, AC-Intermediate, Highly Significant Variables - IRI Rank.

Description	Category	IRI-Rank
Construction −5 month (Cold)	01-General	0.5
Initial IRI +12	02-Analysis	0.1
Initial IRI −13	02-Analysis	0.1
Latitude −1.1	04-Climate	0.3
Longitude +0.7	04-Climate	0.2
Water Table Depth 1'	04-Climate	0.2
Water Table Depth at 2'	04-Climate	0.3
Water Table Depth at 4'	04-Climate	0.5
AC Layer +1.5"	07-AC	0.4
AC Layer −1.5"	07-AC	0.2
AC G* Delta×3	07-AC-Binder-SP-1	0.3
AC Air Voids +3.8%	07-AC-General	0.1
AC Air Voids −1.7%	07-AC-General	0.3
AC Eff Binder Cont +3%	07-AC-General	0.5
AC Eff Binder Cont −3%	07-AC-General	0.2
CS High Soil Water Value	08-CS-ICM	0.4
CS Uncompacted	08-CS-ICM	0.5
CS Resilient Mod×2	08-CS-Str	0.3
CS Resilient Mod/2	08-CS-Str	0.2
CHLS P200 +70%	09-CHLS-ICM	0.4
CHLS PI −2	09-CHLS-ICM	0.4

Table F-10. Wet-Warm, AC-Intermediate, Significant Variables - IRI Rank.

Description	Category	IRI-Rank
Base Construction −2 month	01-General	1.3
Local Road TTC Class 9	02-Site	0.7
Minor Arterial TTC Class 4	02-Site	1.2
AADT −193 (20%)	03-Traffic	1.1
AADT +232 (20%)	03-Traffic	0.9
Wander 2" Less	03-Traffic-General	1.3
Wander 2" More	03-Traffic-General	1.6
All Tire Press +30 psi	03-Traffic-General-Axle	2.4
All Tire Press −30 psi	03-Traffic-General-Axle	1.3
Dual Tire Press +30 psi	03-Traffic-General-Axle	2.4
Dual Tire Press −30 psi	03-Traffic-General-Axle	1.3
Latitude +0.6	04-Climate	1.0
Longitude −0.8	04-Climate	0.8
AC Visc Grade 30	07-AC-Binder-AC-3	1.6
AC PG Grade 58-34	07-AC-Binder-SP-3	1.8
AC PG Grade 76-22	07-AC-Binder-SP-3	1.0
AC PG Grade 82-28	07-AC-Binder-SP-3	1.0
AC % Pass #200 −2.5%	07-AC-Mix	2.4
AC % Retained #4 +10%	07-AC-Mix	2.4
AC Dynamic Mod Def	07-AC-Mix	2.4
AC Dynamic Mod×1.5	07-AC-Mix	0.7
AC Dynamic Mod/1.5	07-AC-Mix	0.7
CS Low Soil Water Value	08-CS-ICM	0.9
CS Unit Wt −6 pcf	08-CS-ICM	0.9
Crushed Stone Layer −1"	08-CS-Str	2.4
CHLS Low Soil Water Value	09-CHLS-ICM	1.6
CHLS P200 −10%	09-CHLS-ICM	0.6
CHLS PI +4	09-CHLS-ICM	2.1
CHLS Uncompacted	09-CHLS-ICM	2.1
CHLS Unit Wt −12 pcf	09-CHLS-ICM	2.1
CHLS Unit Wt +8 pcf	09-CHLS-ICM	1.8
CH Lime Stab Layer +2"	09-CHLS-Str	1.4
CH Lime Stab Layer −2"	09-CHLS-Str	0.9
CHLS Resilient Mod×0.7	09-CHLS-Str	1.6
CHLS Resilient Mod×1.3	09-CHLS-Str	2.4
SG Def Soil Water Value	10-SG-ICM	0.7
SG P200 −10%	10-SG-ICM	2.4
SG PI −10	10-SG-ICM	1.3
SG Sat Hyd Cond×100	10-SG-ICM	2.1
SG Uncompacted	10-SG-ICM	1.5
SG Unit Wt +23.4 pcf	10-SG-ICM	0.8
SG Unit Wt −16.7 pcf	10-SG-ICM	1.4
SG Def Thick −25"	10-SG-Str	0.6
SG Resilient Mod +4 ksi	10-SG-Str	2.4
BR Deleted	11-BR	1.0

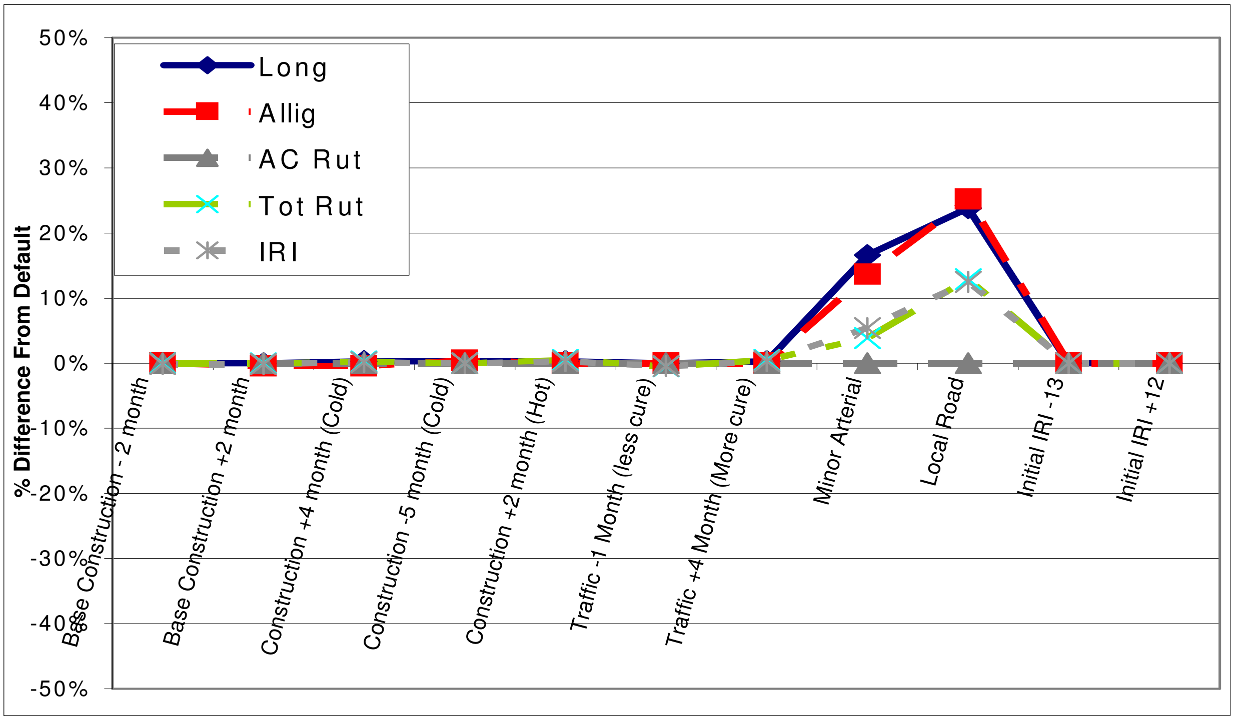

Figure F-1. Wet-Warm, AC-Intermediate, General Variables.

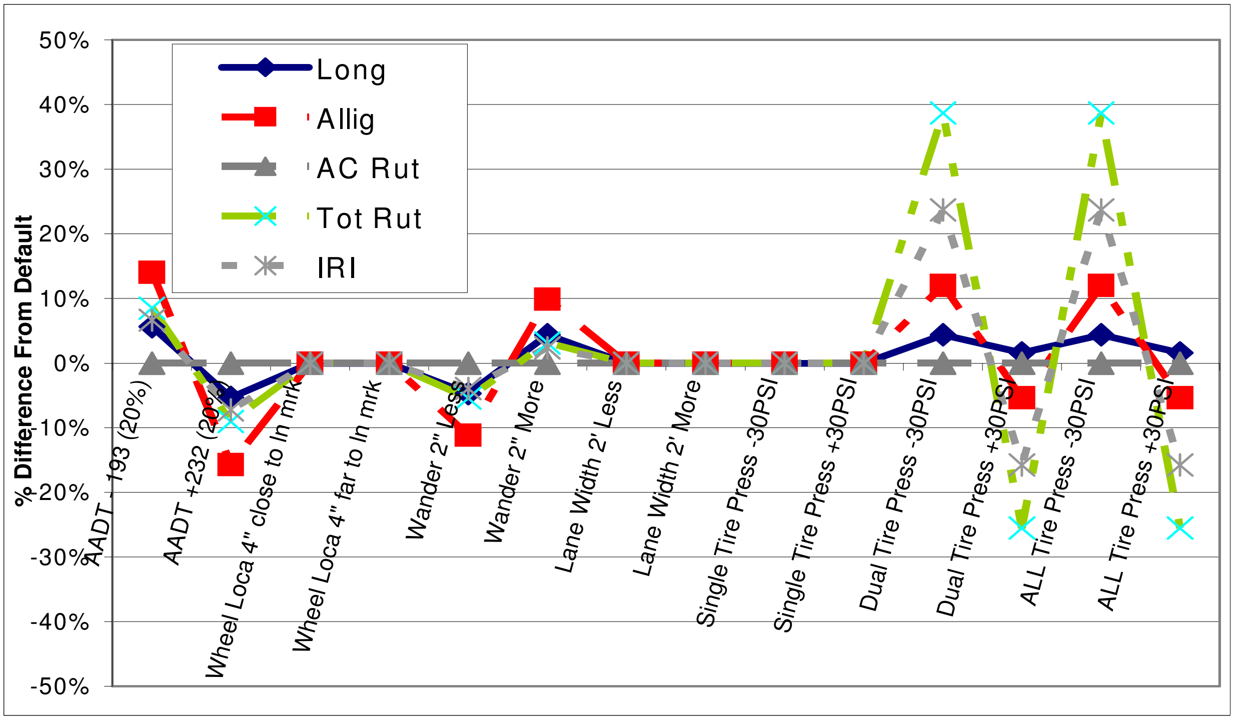

Figure F-2. Wet-Warm, AC-Intermediate, Traffic Variables.

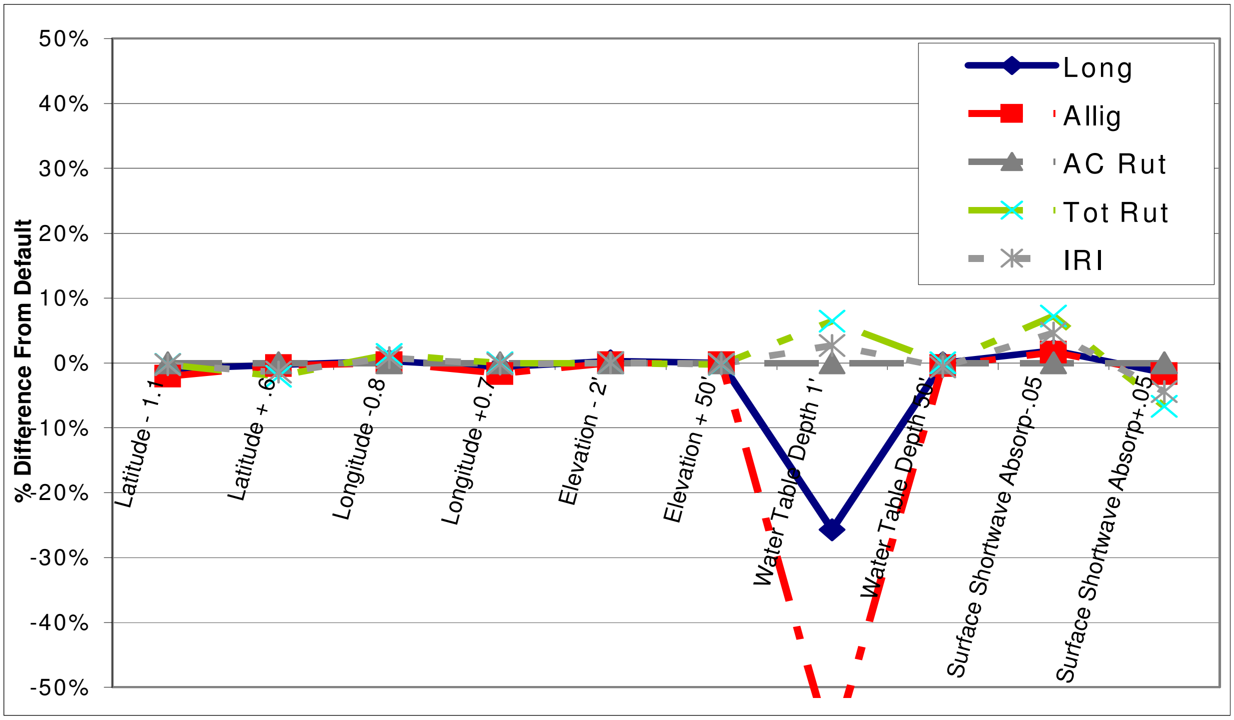

Figure F-3. Wet-Warm, AC-Intermediate, Climate Variables.

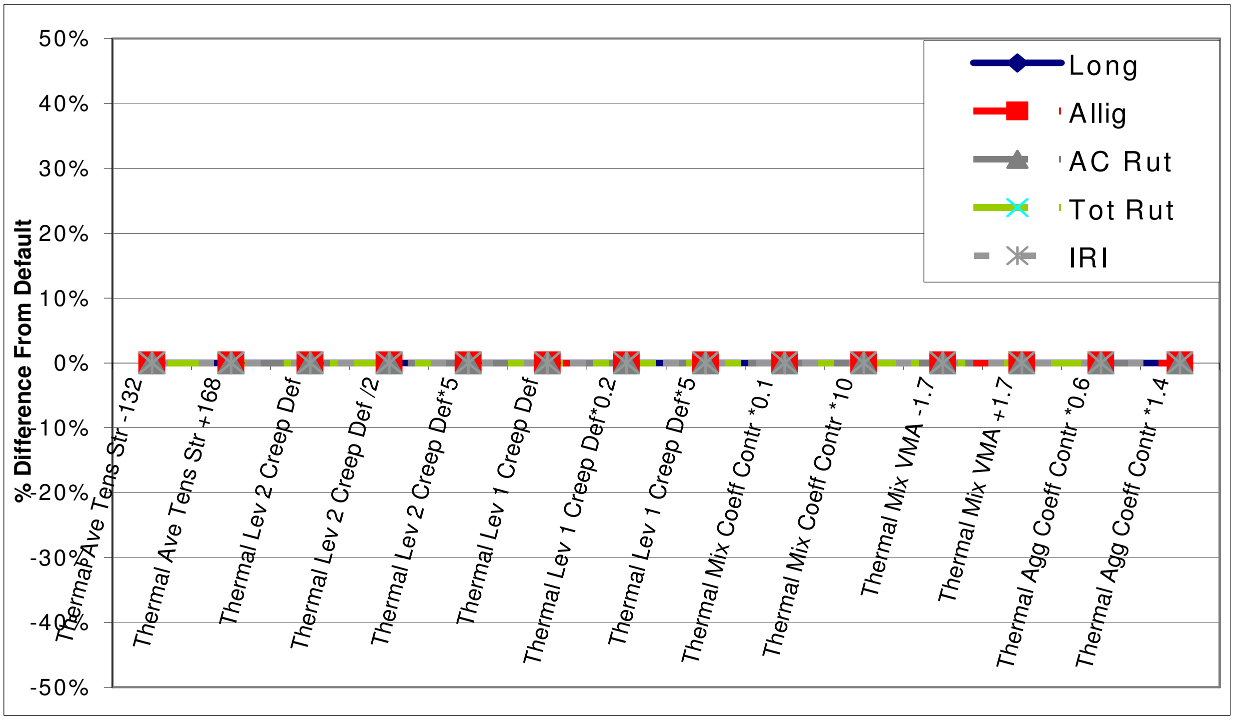

Figure F-4. Wet-Warm, AC-Intermediate, Thermal Variables.

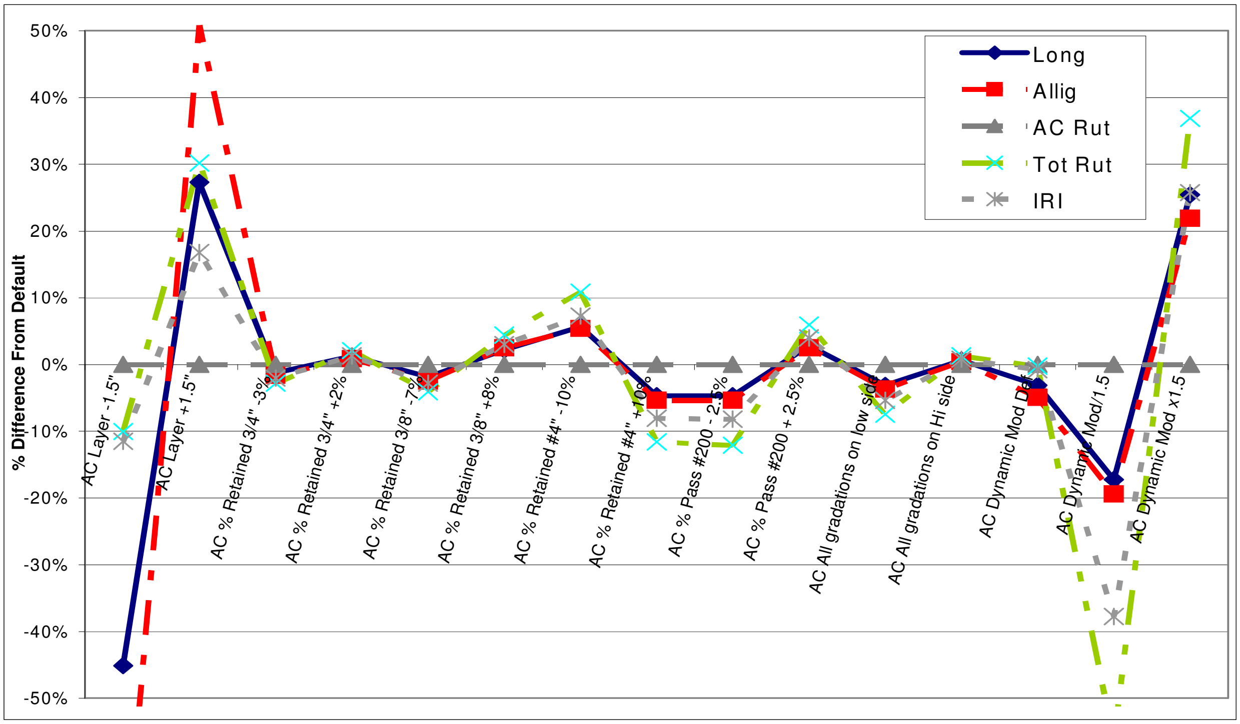

Figure F-5. Wet-Warm, AC-Intermediate, AC Mix Variables.

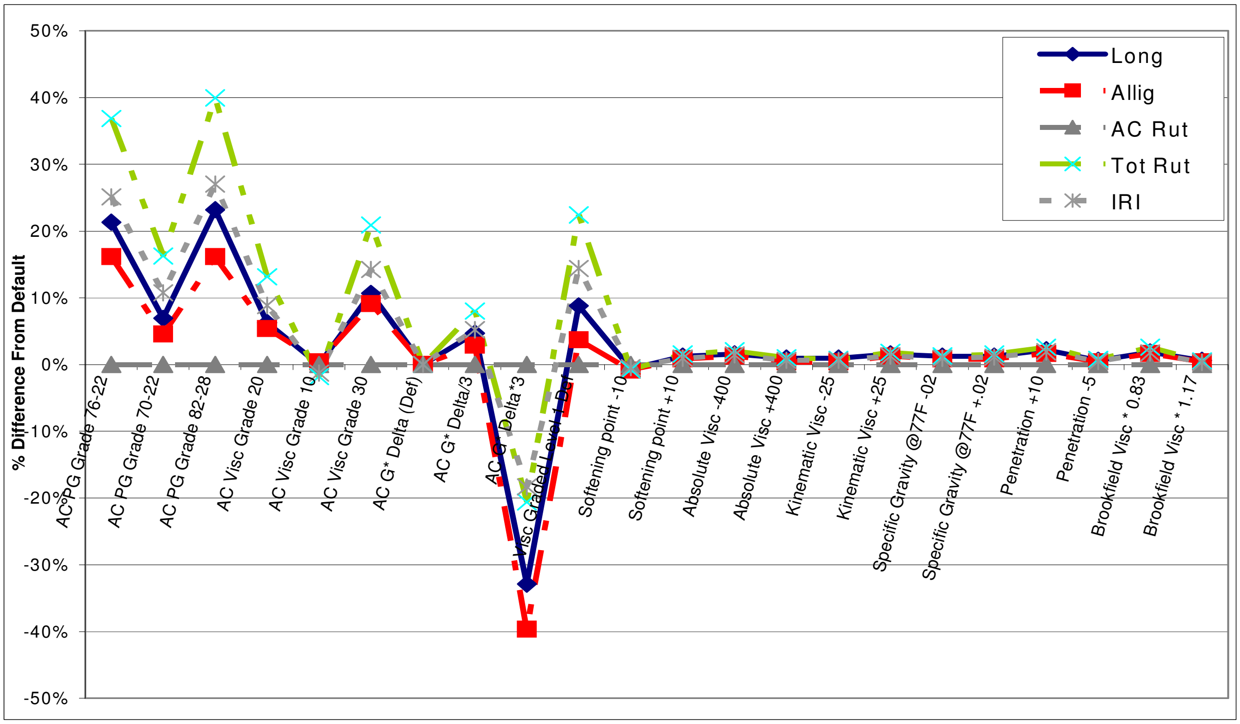

Figure F-6. Wet-Warm, AC-Intermediate, AC Binder Variables.

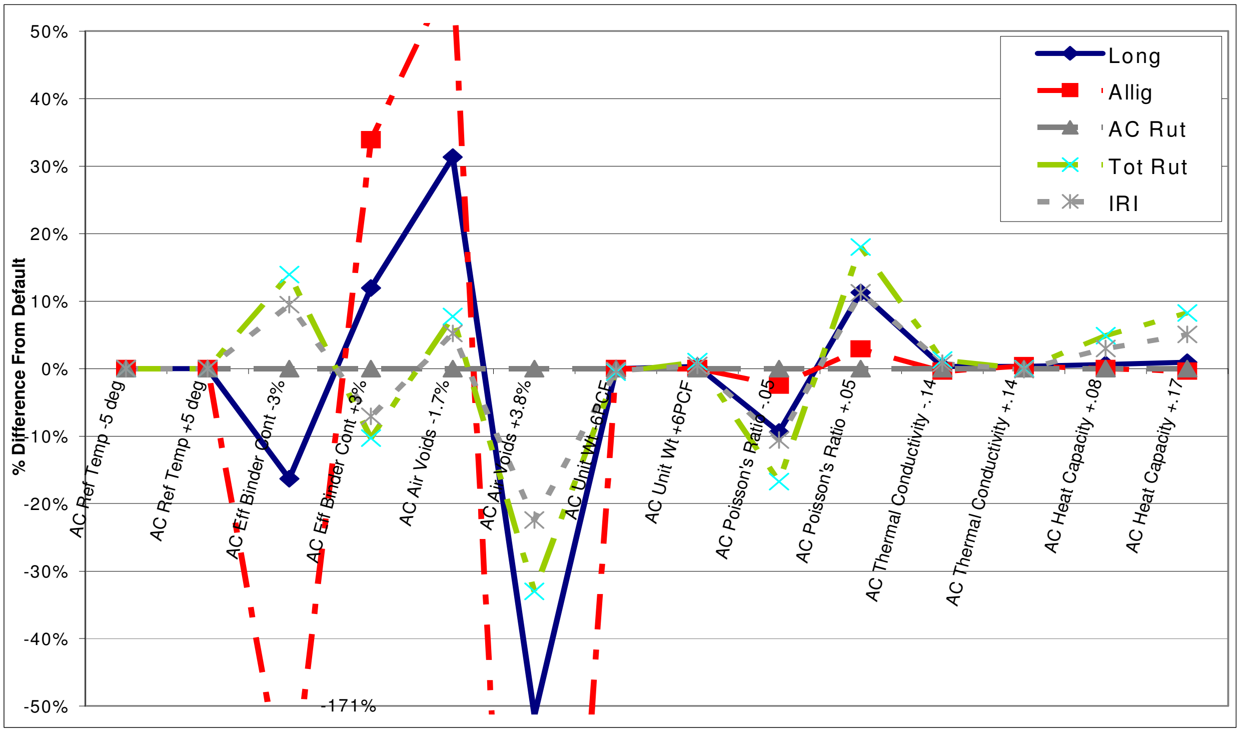

Figure F-7. Wet-Warm, AC-Intermediate, AC General Variables.

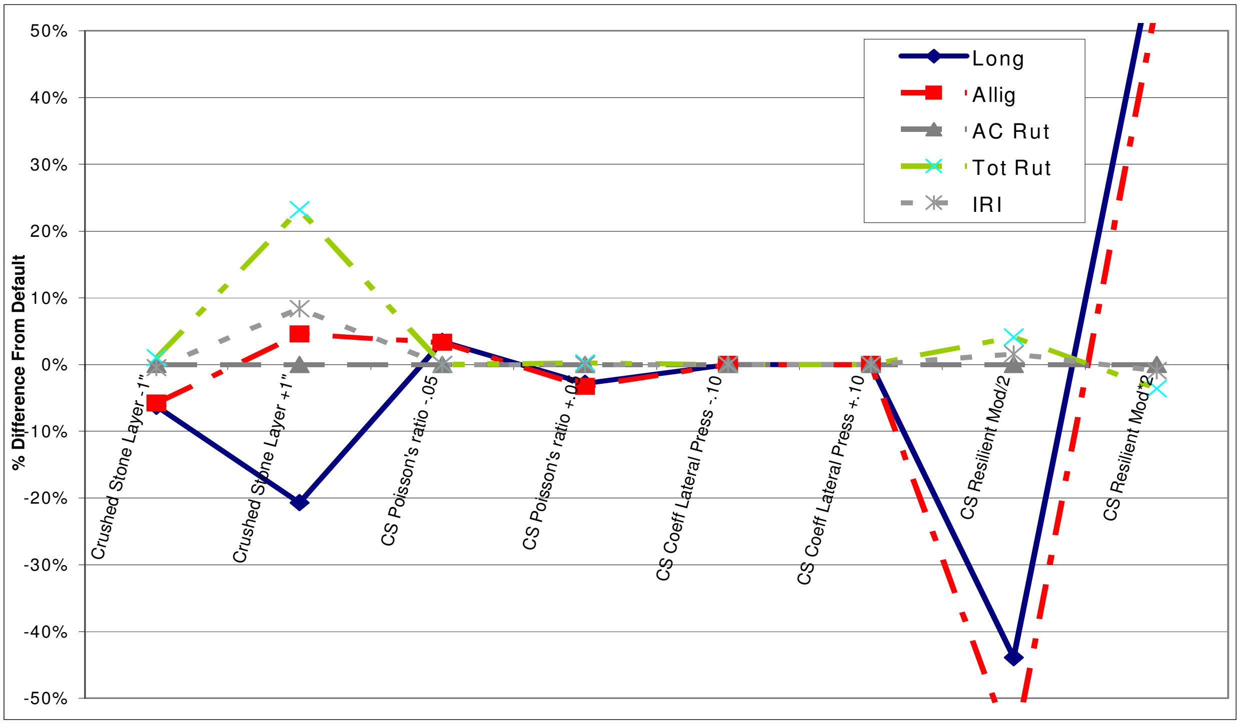

Figure F-8. Wet-Warm, AC-Intermediate, Crushed Stone Structural Variables.

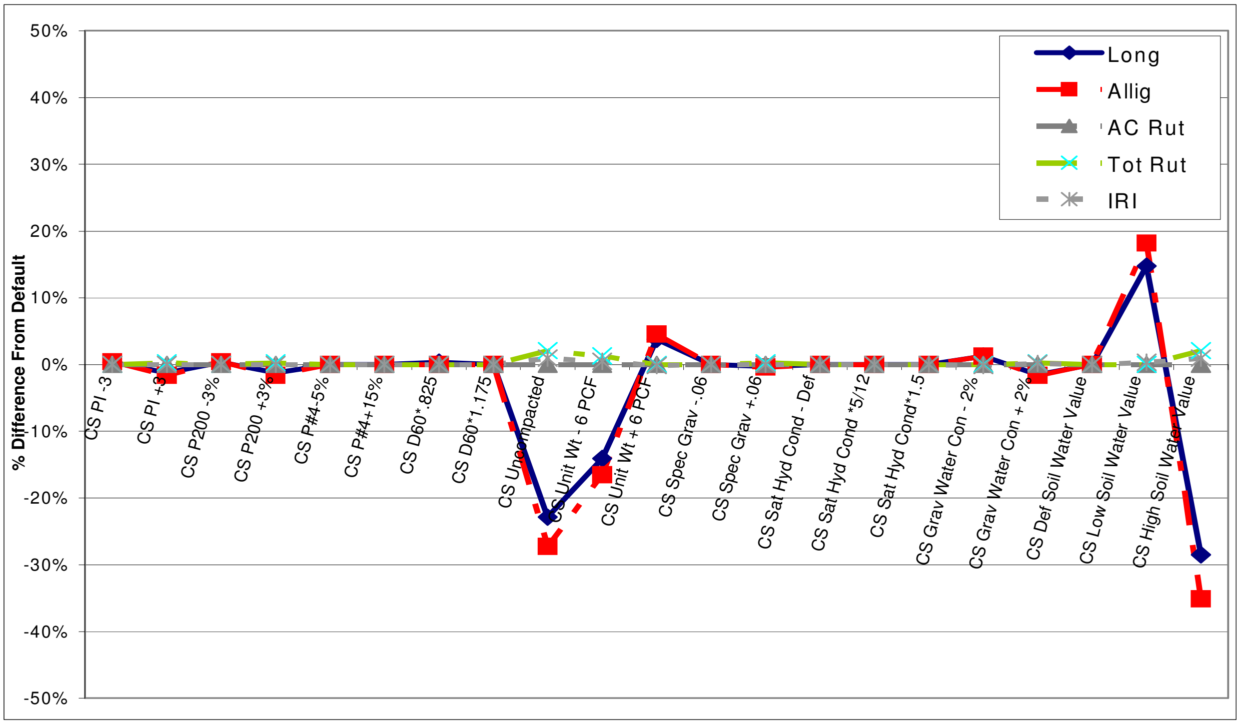

Figure F-9. Wet-Warm, AC-Intermediate, Crushed Stone Climatic Variables.

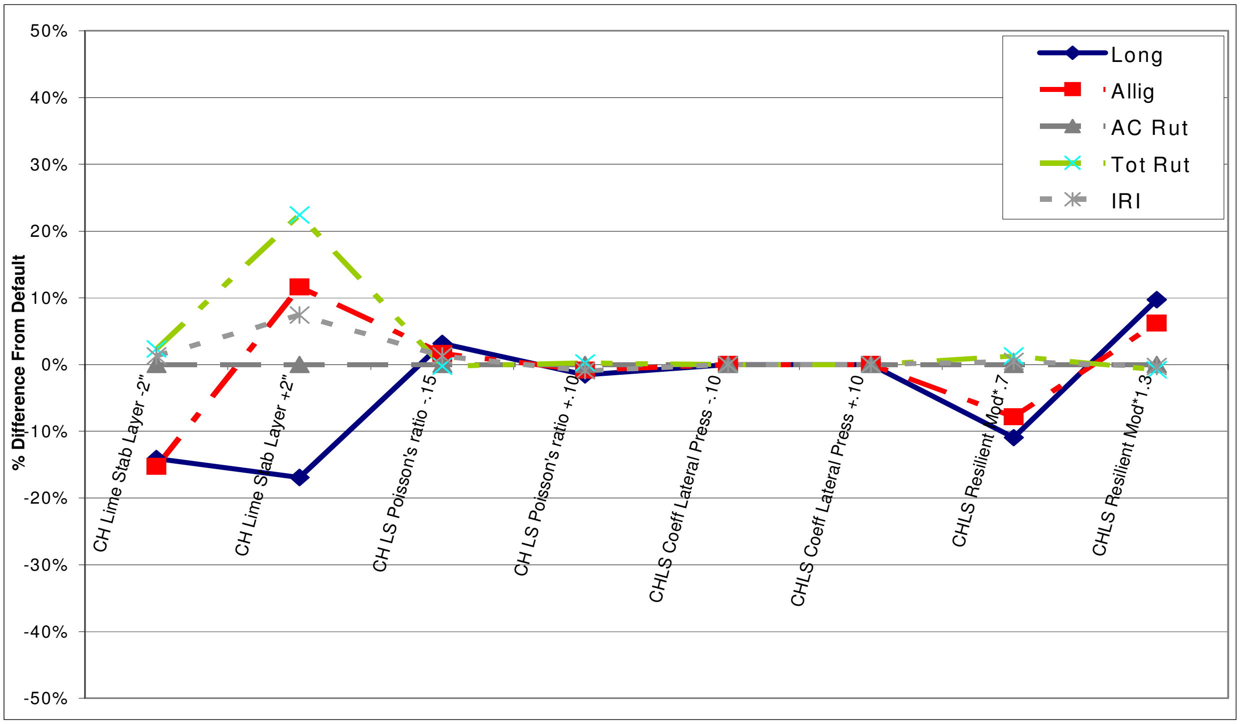

Figure F-10. Wet-Warm, AC-Intermediate, Lime Modified Structural Variables.

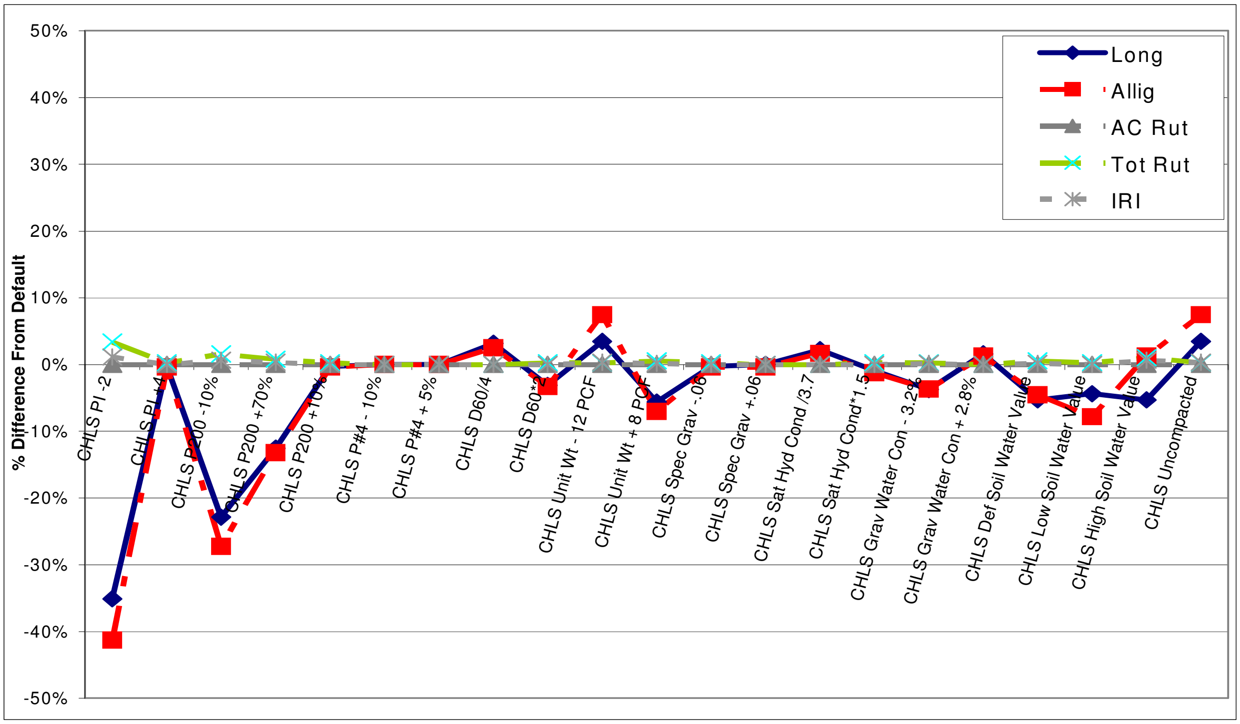

Figure F-11. Wet-Warm, AC-Intermediate, Lime Treated Climatic Variables.

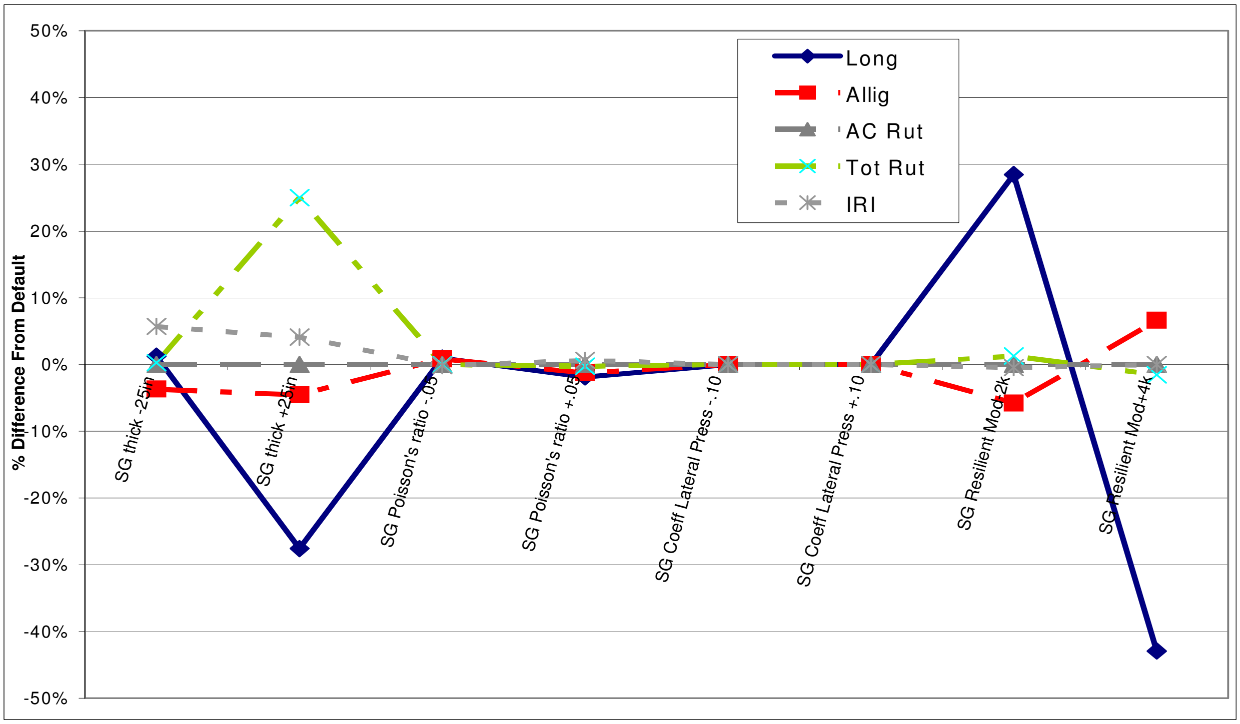

Figure F-12. Wet-Warm, AC-Intermediate, Subgrade Structural Variables.

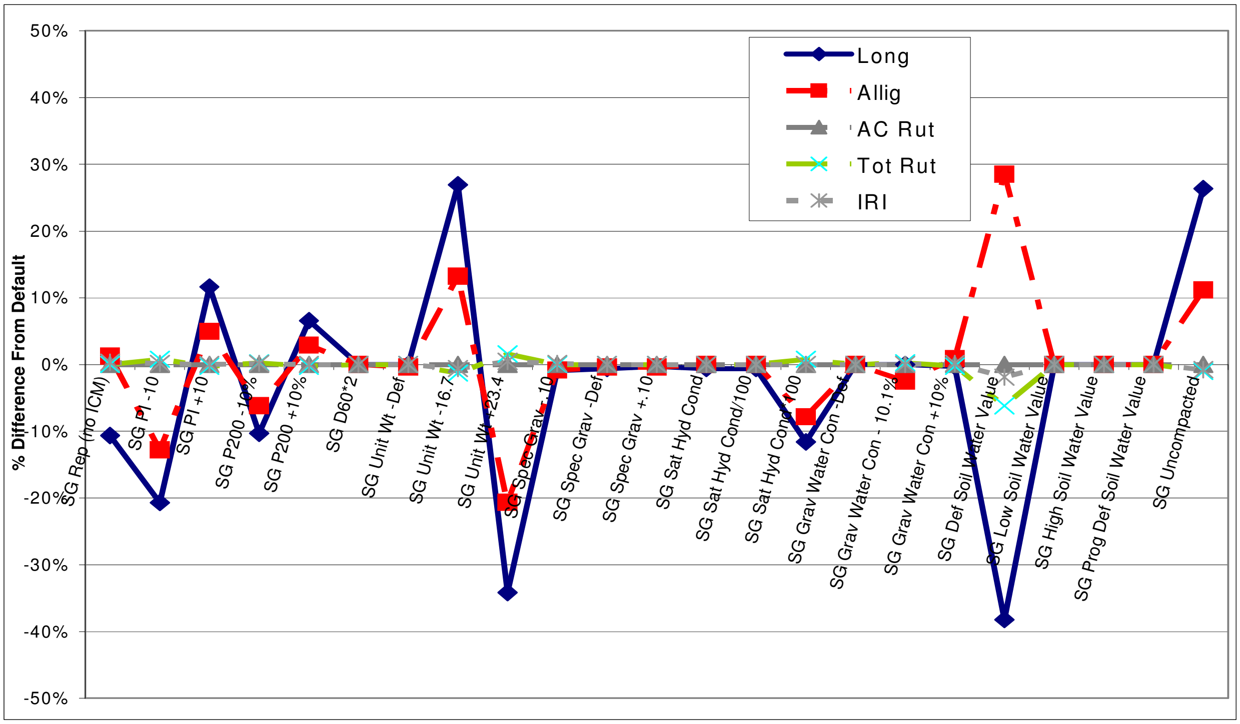

Figure F-13. Wet-Warm, AC-Intermediate, Subgrade Climatic Variables.

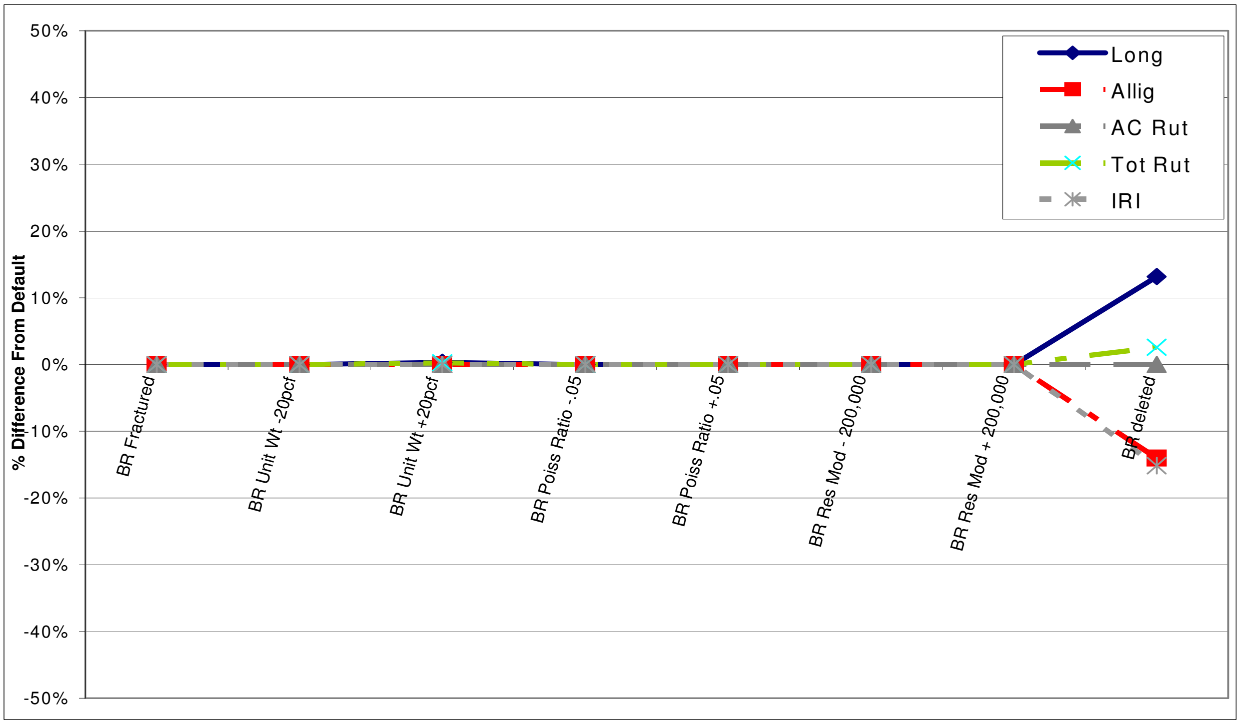

Figure F-14. Wet-Warm, AC-Intermediate, Bedrock Variables.

Table F-11. Results of Wet-Warm, AC-Intermediate, General Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
Base Construction −2 month	=	=	=	<	> >
Base Construction +2 month	=	<	=	<	<
Construction +2 month (Hot)	>	=	>	>	=
Construction +4 month (Cold)	>	<	>	>	=
Construction −5 month (Cold)	<	>	=	=	< < <
Traffic +4 month (More Cure)	>	=	>	>	=
Traffic −1 month (Less Cure)	=	=	<	<	=
Initial IRI +12	=	=	=	=	< < <
Initial IRI −13	=	=	=	=	> > >
Local Road TTC Class 9	> > >	> >	> >	> >	> >
Minor Arterial TTC Class 4	> > >	> >	> >	> >	> >

Table F-12. Results of Wet-Warm, AC-Intermediate, Traffic Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
AADT −193 (20%)	> >	> >	> >	> >	> >
AADT +232 (20%)	< <	< <	< <	< <	< <
Lane Width 2' Less	=	=	=	=	=
Lane Width 2' More	=	=	=	=	=
Wander 2" Less	< <	< <	< <	< <	< <
Wander 2" More	> >	> >	>	>	> >
Wheel Loca 4" Close to Ln Mrk	=	=	=	=	=
Wheel Loca 4" Far to Ln Mrk	=	=	=	=	=
All Tire Press +30 psi	<	<	< < <	< < <	< <
All Tire Press −30 psi	> >	> >	> > >	> > >	> >
Dual Tire Press +30 psi	<	<	< < <	< < <	< <
Dual Tire Press −30 psi	> >	> >	> > >	> > >	> >
Single Tire Press +30 psi	=	=	=	=	=
Single Tire Press −30 psi	=	=	=	=	=

Table F-13. Results of Wet-Warm, AC-Intermediate, Climate Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
Elevation −2'	>	=	=	=	=
Elevation +50'	=	=	<	<	>
Latitude −1.1	>	<	<	<	> > >
Latitude +0.6	<	<	<	<	< <
Longitude +0.7	>	<	=	<	> > >
Longitude −0.8	>	=	>	>	> >
Water Table Depth 1'	< < <	< < <	> >	> >	< < <
Water Table Depth 50'	=	<	=	<	=
Water Table Depth at 2'	< <	< < <	> >	>	< < <
Water Table Depth at 4'	<	< < <	> >	>	< < <
Water Table Depth at 6'	> > >	>	>	>	=

Table F-14. Results of Wet-Warm, AC-Intermediate, AC Thermal Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
Thermal Agg Coeff Contr×0.6	=	=	=	=	=
Thermal Agg Coeff Contr×1.4	=	=	=	=	=
Thermal Ave Tens Str +168	=	=	=	=	=
Thermal Ave Tens Str −132	=	=	=	=	=
Thermal Lev 1 Creep Def	=	=	=	=	=
Thermal Lev 1 Creep Def×0.2	=	=	=	=	=
Thermal Lev 1 Creep Def×5	=	=	=	=	=
Thermal Lev 2 Creep Def	=	=	=	=	=
Thermal Lev 2 Creep Def/2	=	=	=	=	=
Thermal Lev 2 Creep Def×5	=	=	=	=	=
Thermal Mix Coeff Contr×0.1	=	=	=	=	=
Thermal Mix Coeff Contr×10	=	=	=	=	=
Thermal Mix VMA +1.7%	=	=	=	=	=
Thermal Mix VMA −1.7%	=	=	=	=	=
Surface Shortwave Absorp −0.05	>	>	> >	> >	>
Surface Shortwave Absorp +0.05	<	<	< <	< <	<

Table F-15. Results of Wet-Warm, AC-Intermediate, AC Binder Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
AC Layer +1.5"	> > >	> > >	> > >	> > >	> > >
AC Layer −1.5"	< < <	< < <	< <	< <	< < <
Absolute Visc +400	>	>	>	>	>
Absolute Visc −400	>	>	>	>	>
Brookfield Visc×0.83	>	>	>	>	>
Brookfield Visc×1.17	>	>	>	>	>
Kinematic Visc (325)	>	>	>	>	>
Kinematic Visc +25	>	>	>	>	>
Kinematic Visc −25	>	>	>	>	>
Penetration +10	> >	>	>	>	>
Penetration −5	>	>	>	>	>
Softening Point +10 °F	>	>	>	>	>
Softening Point −10 °F	>	<	<	<	=
Specific Gravity @77°F +0.02	>	>	>	>	>
Specific Gravity @77°F −0.02	>	>	>	>	>
Visc Graded Level 1 Def	> >	>	> > >	> > >	>
AC Visc Grade 10	=	>	<	<	=
AC Visc Grade 20	> >	>	> >	> >	>
AC Visc Grade 30	> > >	> >	> > >	> > >	> >
AC G* Delta (Def)	=	=	=	=	=
AC G* Delta×3	< < <	< < <	< < <	< < <	< < <
AC G* Delta/3	> >	>	> >	> >	>
AC PG Grade 58-34	< <	< <	< < <	< < <	< <
AC PG Grade 64-28 Def	=	=	=	=	=
AC PG Grade 70-22	> >	>	> > >	> >	>
AC PG Grade 76-22	> > >	> >	> > >	> > >	> >
AC PG Grade 82-28	> > >	> >	> > >	> > >	> >

Table F-16. Results of Wet-Warm, AC-Intermediate, General AC Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
AC Air Voids +3.8%	< < <	< < <	< < <	< < <	< < <
AC Air Voids −1.7%	> > >	> > >	> >	> >	> > >
AC Eff Binder Cont +3%	> > >	> > >	< <	< <	> > >
AC Eff Binder Cont −3%	< < <	< < <	> >	> >	< < <
AC Heat Capacity +0.08	>	=	> >	> >	=
AC Heat Capacity +0.17	<	<	> >	> >	<
AC Poisson’s Ratio −0.05	< <	<	< < <	< <	<
AC Poisson’s Ratio +0.05	> > >	>	> > >	> >	>
AC Ref Temp +5 °F	=	=	=	=	=
AC Ref Temp −5 °F	=	=	=	=	=
AC Thermal Conductivity −0.14	>	<	>	>	=
AC Thermal Conductivity +0.14	>	>	=	<	=
AC Unit Wt +6 pcf	>	=	>	>	=
AC Unit Wt −6 pcf	=	=	<	<	=

Table F-17. Results of Wet-Warm, AC-Intermediate, AC Mix Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
AC % Pass #200 −2.5%	< <	<	< <	< <	< <
AC % Pass #200 +2.5%	> >	>	> >	> >	>
AC % Retained #4 +10%	< <	<	< <	< <	< <
AC % Retained #4 −10%	> >	>	> >	> >	>
AC % Retained 3/4" +2%	>	>	>	>	>
AC % Retained 3/4" −3%	<	<	<	<	<
AC % Retained 3/8" +8%	> >	>	> >	> >	>
AC % Retained 3/8" −7%	<	<	< <	< <	<
AC All Gradations on Hi Side	>	>	>	>	=
AC All Gradations on Low Side	< <	<	< <	< <	<
AC Dynamic Mod Def	< <	<	<	<	< <
AC Dynamic Mod ×1.5	> > >	> >	> > >	> > >	> >
AC Dynamic Mod/1.5	< < <	< <	< < <	< < <	< <

Table F-18. Results of Wet-Warm, AC-Intermediate, Crushed Stone ICM Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
CS D60×0.825	>	=	=	=	=
CS D60×1.175	=	=	=	=	=
CS Def Soil Water Value	=	=	=	=	=
CS Grav Water Con −2%	>	>	=	<	>
CS Grav Water Con +2%	<	<	>	>	<
CS Grav Water Con - Def	=	<	=	=	<
CS High Soil Water Value	<<<	<<<	>	>	<<<
CS Low Soil Water Value	>>>	>>	=	>	>>
CS P#4 +15%	=	=	=	=	=
CS P#4 −5%	=	=	=	=	=
CS P200 +3%	<	<	>	=	<
CS P200 −3%	>	>	=	=	=
CS PI +3	<	<	>	=	<
CS PI −3	>	>	=	=	=
CS Sat Hyd Cond - Def	=	=	=	=	=
CS Sat Hyd Cond (Prog Def)	=	=	=	=	=
CS Sat Hyd Cond×5/12	=	=	=	=	=
CS Sat Hyd Cond×1.5	=	=	=	=	=
CS Soil Water Prog Def	=	=	=	=	=
CS Spec Grav - Def	=	<	=	=	<
CS Spec Grav −0.06	=	=	=	=	=
CS Spec Grav +0.06	<	<	>	=	<
CS Uncompacted	<<<	<<<	>	>	<<<
CS Unit Wt −6 pcf	<<<	<<	>	>	<<
CS Unit Wt - Def	=	=	=	=	=
CS Unit Wt +6 pcf	>>	>	=	<	>

Table F-19. Results of Wet-Warm, AC-Intermediate, Crushed Stone Strength Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
Crushed Stone Layer +1"	>>>	>	>>>	>>	>
Crushed Stone Layer −1"	<<	<<	>	<	<<
CS Coeff Lateral Press −0.10	=	=	=	=	=
CS Coeff Lateral Press +0.10	=	=	=	=	=
CS Poisson's Ratio −0.05	>>	>	=	=	>
CS Poisson's Ratio +0.05	<<	<	>	=	<
CS Resilient Mod×2	>>>	>>>	<<	<	>>>
CS Resilient Mod/2	<<<	<<<	>>	>	<<<

Table F-20. Results of Wet-Warm, AC-Intermediate, Crushed Stone ICM Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
CHLS D60×2	<<	<	>	=	<
CHLS D60/4	>>	>	=	=	>
CHLS Def Soil Water Value	<<	<	>	>	<
CHLS Grav Water Con −3.2%	<<	<	>	>	<
CHLS Grav Water Con +2.8%	>	>	=	=	>
CHLS Grav Water Con - Def	=	=	=	=	=
CHLS High Soil Water Value	>>	>	>	>	>
CHLS Low Soil Water Value	<<	<<	>	=	<<
CHLS P#4 −10%	=	=	=	=	=
CHLS P#4 +5%	=	=	=	=	=
CHLS P200 +10%	<	<	>	=	<
CHLS P200 +70%	<<<	<<	>	>	<<<
CHLS P200 −10%	<<<	<<<	>	>	<<
CHLS PI +4	<	<	>	=	<<
CHLS PI −2	<<<	<<<	>	>	<<<
CHLS Sat Hyd Cond/3.7	>>	>	=	=	>
CHLS Sat Hyd Cond - Def	=	=	=	=	=
CHLS Sat Hyd Cond×1.5	<	<	>	=	<
CHLS Soil Water Prog Def	=	=	=	=	=
CHLS Spec Grav −0.06	<	<	>	=	<
CHLS Spec Grav +0.06	=	<	=	=	=
CHLS Spec Grav - Def	<	<	=	=	<
CHLS Uncompacted	>>	>>	>	>	>>
CHLS Unit Wt −12 pcf	>>	>>	>	>	>>
CHLS Unit Wt - Def	=	=	=	=	=
CHLS Unit Wt +8 pcf	<<	<<	>	>	<<

Table F-21. Results of Wet-Warm, AC-Intermediate, Lime Treated Strength Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
CH Lime Stab Layer + 2"	> > >	> >	> > >	> >	> >
CH Lime Stab Layer −2"	< < <	< <	>	>	< <
CH LS Poisson’s Ratio −0.15	> >	>	<	>	>
CH LS Poisson’s Ratio +0.10	<	<	>	<	<
CHLS Coeff Lateral Press −0.10	=	=	=	=	=
CHLS Coeff Lateral Press +0.10	=	=	=	=	=
CHLS Resilient Mod×0.7	< < <	< <	>	>	< <
CHLS Resilient Mod×1.3	> >	> >	<	<	> >

Table F-22. Results of Wet-Warm, AC-Intermediate, Subgrade ICM Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
SG D60×2	=	=	=	=	=
SG Def Soil Water Value	> > >	> > >	< <	<	> >
SG Grav Water Con −10.1%	=	<	>	=	<
SG Grav Water Con +10%	>	>	<	>	>
SG Grav Water Con - Def	=	=	=	=	=
SG High Soil Water Value	=	=	=	=	=
SG Low Soil Water Value	=	=	=	=	=
SG P200 +10%	> >	>	<	=	>
SG P200 −10%	< < <	< <	>	>	< <
SG PI +10	> > >	>	<	=	>
SG PI −10	< < <	< <	>	>	< <
SG Prog Def Soil Water Value	=	=	=	=	=
SG Rep (No ICM)	> > >	>	=	>	>
SG Sat Hyd Cond	>	=	=	=	=
SG Sat Hyd Cond×100	< < <	< <	>	=	< <
SG Sat Hyd Cond/100	>	=	=	=	=
SG Spec Grav −0.10	<	<	=	>	<
SG Spec Grav +0.10	>	<	=	=	=
SG Spec Grav - Def	<	<	=	=	<
SG Uncompacted	> > >	> >	<	<	> >
SG Unit Wt +23.4 pcf	< < <	< <	>	>	< <
SG Unit Wt −16.7 pcf	> > >	> >	<	<	> >
SG Unit Wt - Def	=	<	=	=	=

Table F-23. Results of Wet-Warm, AC-Intermediate, Subgrade Strength Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
SG Coeff Lateral Press −0.10	=	=	=	=	=
SG Coeff Lateral Press +0.10	=	=	=	=	=
SG Def Thick −25"	> > >	> > >	<	<	> >
SG Poisson’s Ratio −0.05	>	>	=	<	>
SG Poisson’s Ratio +0.05	<	<	<	>	<
SG Resilient Mod +4 ksi	> > >	> >	<	=	> >
SG Resilient Mod −2 ksi	< < <	< <	>	<	<
SG Thick +25"	< < <	<	> > >	> >	<
SG Thick −25"	<	<	>	> >	<

Table F-24. Results of Wet-Warm, AC-Intermediate, Bedrock Variables.

Description	Long Rank	Allig Rank	ACRut Rank	TotRut Rank	IRI Rank
BR Deleted	< < <	< <	>	< < <	< <
BR Fractured	=	=	=	=	=
BR Poiss Ratio −0.05	=	=	=	=	=
BR Poiss Ratio +0.05	=	=	=	=	=
BR Res Mod −200,000	=	=	=	=	=
BR Res Mod +200,000	=	=	=	=	=
BR Unit Wt +20 pcf	>	=	>	=	=
BR Unit Wt −20 pcf	=	=	=	=	=

APPENDIX G

DRY-COLD, AC-THICK RESULTS

Table G-1. Dry-Cold, AC-Thick, Highly Significant Variables - Longitudinal Cracking.

Description	Category	Long-Rank
Local Road TTC Class 9	02-Site	0.1
Minor Arterial TTC Class 4	02-Site	0.1
All Tire Press +30 psi	03-Traffic-General-Axle	0.2
All Tire Press −30 psi	03-Traffic-General-Axle	0.1
Dual Tire Press +30 psi	03-Traffic-General-Axle	0.2
Dual Tire Press −30 psi	03-Traffic-General-Axle	0.1
Water Table Depth at 1'	04-Climate	0.4
AC Top Layer −1"	07-AC	0.5
Absolute Visc +200	07-AC-Binder-AC-1	0.2
AC Visc Grade 20	07-AC-Binder-AC-3	0.4
AC Visc Grade 5	07-AC-Binder-AC-3	0.3
2nd AC G* Delta×3	07-AC-Binder-SP-1	0.1
2nd AC G* Delta/3	07-AC-Binder-SP-1	0.1
AC G* Delta×3	07-AC-Binder-SP-1	0.4
AC G* Delta/3	07-AC-Binder-SP-1	0.4
AC PG Grade 58-34	07-AC-Binder-SP-3	0.2
AC PG Grade 76-22	07-AC-Binder-SP-3	0.1
AC Air Voids +2.5%	07-AC-General	0.2
AC Air Voids −2%	07-AC-General	0.1
AC Poisson’s Ratio −0.05	07-AC-General	0.5
AC Poisson’s Ratio +0.05	07-AC-General	0.4
2nd AC Dynamic Mod/1.5	07-AC-Mix	0.5
2nd AC Dynamic Mod ×1.5	07-AC-Mix	0.5
AC Dynamic Mod Def	07-AC-Mix	0.0
AC Dynamic Mod ×1.5	07-AC-Mix	0.1
AC Dynamic Mod/1.5	07-AC-Mix	0.1
SG Def Soil Water Value	10-SG-ICM	0.1
SG High Soil Water Value	10-SG-ICM	0.1
SG Low Soil Water Value	10-SG-ICM	0.1
SG PI −10	10-SG-ICM	0.4
SG Sat Hyd Cond×10	10-SG-ICM	0.3
SG Sat Hyd Cond/10	10-SG-ICM	0.3
SG Resilient Modulus −5 ksi	10-SG-Str	0.3

Table G-2. Dry-Cold, AC-Thick, Significant Variables - Longitudinal Cracking.

Description	Category	Long-Rank
AADT −2318 (20%)	03-Traffic	0.8
AADT +2318 (20%)	03-Traffic	1.2
Wander 2" More	03-Traffic-General	2.3
Elevation −1500'	04-Climate	1.2
Elevation +1500'	04-Climate	1.2
Longitude −1	04-Climate	2.3
Surf Shortwave Absorp −0.05	06-Drain	1.1
Surf Shortwave Absorp +0.05	06-Drain	1.2
AC 2nd AC Layer +1"	07-AC	1.0
AC 2nd AC Layer −1"	07-AC	0.8
AC Top Layer +1"	07-AC	0.8
Penetration +30	07-AC-Binder-AC-1	1.4
Softening Point −10	07-AC-Binder-AC-1	2.3
2nd AC Visc Grade 30 Deflt	07-AC-Binder-AC-3	0.6
2nd AC Visc Grade 40	07-AC-Binder-AC-3	1.6
AC Visc Grade 10	07-AC-Binder-AC-3	1.6
2nd AC PG Grade 70-28	07-AC-Binder-SP-3	0.6
2nd AC PG Grade 82-16	07-AC-Binder-SP-3	1.2
2nd AC Air Voids +2.5%	07-AC-General	0.8
2nd AC Air Voids −2%	07-AC-General	1.4
2nd AC Eff Binder Content +3%	07-AC-General	1.6
2nd AC Eff Binder Content −3%	07-AC-General	1.4
2nd AC Poisson’s Ratio −0.05	07-AC-General	2.3
2nd AC Poisson’s Ratio +0.05	07-AC-General	2.3
AC Eff Binder Content +3%	07-AC-General	1.2
AC Eff Binder Content −3%	07-AC-General	1.4
AC Heat Capacity +0.08	07-AC-General	1.2
AC Heat Capacity +0.17	07-AC-General	0.6
2nd AC % Pass #200 −3%	07-AC-Mix	1.4
2nd AC All Gradations Low	07-AC-Mix	1.2
AC % Pass #200 +2%	07-AC-Mix	1.0
AC 2ndAC % Retained #4 +7.5%	07-AC-Mix	2.3
AC 2ndAC % Retained #4 −7.5%	07-AC-Mix	2.3
AC All Gradations on Hi Side	07-AC-Mix	0.9
AC All Gradations on Low Side	07-AC-Mix	1.2
AC Top % Retained #4" +6%	07-AC-Mix	0.7
AC Top % Retained #4" −6%	07-AC-Mix	0.6
AC Top % Retained 3/4" +2%	07-AC-Mix	1.9
AC Top % Retained 3/8" +7.5%	07-AC-Mix	1.0
AC Top % Retained 3/8" −7.5%	07-AC-Mix	1.1

Table G-2. Dry-Cold, AC-Thick, Significant Variables - Longitudinal Cracking (Continued).

CHLS Low Soil Water Values	09-CHLS-ICM	1.9
CHLS PI −2	09-CHLS-ICM	0.7
CHLS Uncompacted	09-CHLS-ICM	2.3
CH Lime Stab Layer −2"	09-CHLS-Str	1.9
CHLS Resilient Modulus×0.7	09-CHLS-Str	1.6
CHLS Resilient Modulus×1.3	09-CHLS-Str	2.3
SG Sat Hyd Cond	10-SG-ICM	1.0
SG Spec Grav +0.05	10-SG-ICM	0.6
SG Resilient Modulus +5 ksi	10-SG-Str	0.6
SG Thickness +25"	10-SG-Str	2.3
SG Thickness −25"	10-SG-Str	1.1

Table G-3. Dry-Cold, AC-Thick, Highly Significant Variables - Alligator Cracking.

Description	Category	Allig-Rank
Local Road TTC Class 9	02-Site	0.5
Water Table Depth at 1'	04-Climate	0.4
2nd AC G* Delta×3	07-AC-Binder-SP-1	0.1
2nd AC G* Delta/3	07-AC-Binder-SP-1	0.1
2nd AC Air Voids +2.5%	07-AC-General	0.2
2nd AC Air Voids −2%	07-AC-General	0.3
2nd AC Eff Binder Content +3%	07-AC-General	0.4
2nd AC Eff Binder Content −3%	07-AC-General	0.2
SG PI −10	10-SG-ICM	0.4
SG Sat Hyd Cond×10	10-SG-ICM	0.4
SG Sat Hyd Cond/10	10-SG-ICM	0.4
SG Spec Grav +0.05	10-SG-ICM	0.2
SG Resilient Modulus −5 ksi	10-SG-Str	0.4

Table G-4. Dry-Cold, AC-Thick, Significant Variables - Alligator Cracking.

Description	Category	Allig-Rank
Minor Arterial TTC Class 4	02-Site	0.8
AADT −2318 (20%)	03-Traffic	1.0
AADT +2318 (20%)	03-Traffic	1.1
Wander 2" LESS	03-Traffic-General	1.6
Wander 2" MORE	03-Traffic-General	1.8
Elevation −1500'	04-Climate	1.6
Elevation +1500'	04-Climate	1.7
Latitude +0.6	04-Climate	1.8
AC 2nd AC Layer +1"	07-AC	0.8
AC 2nd AC Layer −1"	07-AC	0.7
AC Top Layer +1"	07-AC	1.0
AC Top Layer −1"	07-AC	0.9
Absolute Visc + 200	07-AC-Binder-AC-1	1.9
2nd AC Visc Grade 30 Deflt	07-AC-Binder-AC-3	1.6
2nd AC PG Grade 70-28	07-AC-Binder-SP-3	1.4
2nd AC PG Grade 82-16	07-AC-Binder-SP-3	2.4
AC PG Grade 76-22	07-AC-Binder-SP-3	2.4
AC Air Voids +2.5%	07-AC-General	2.4
2nd AC All Gradations on Low Side	07-AC-Mix	2.3
2nd AC Dynamic Modulus/1.5	07-AC-Mix	0.8
2nd AC Dynamic Modulus×1.5	07-AC-Mix	0.8
AC Dynamic Modulus Def	07-AC-Mix	0.8
AC Dynamic Modulus×1.5	07-AC-Mix	1.8
AC Dynamic Modulus/1.5	07-AC-Mix	1.6
CHLS Low Soil Water Values	09-CHLS-ICM	1.1
CHLS PI −2	09-CHLS-ICM	0.6
CHLS Uncompacted	09-CHLS-ICM	1.8
CHLS Unit Wt −10 pcf	09-CHLS-ICM	2.1
CH Lime Stab Layer +2"	09-CHLS-Str	2.3
CH Lime Stab Layer −2"	09-CHLS-Str	1.9
CHLS Resilient Modulus×0.7	09-CHLS-Str	1.2
CHLS Resilient Modulus×1.3	09-CHLS-Str	1.4
SG Def Soil Water Values	10-SG-ICM	1.8
SG High Soil Water Values	10-SG-ICM	2.0
SG Low Soil Water Values	10-SG-ICM	2.3
SG Sat Hyd Cond	10-SG-ICM	0.8
SG Resilient Modulus +5 ksi	10-SG-Str	0.8

Table G-5. Dry-Cold, AC-Thick, Highly Significant Variables - AC Rutting.

Description	Category	ACRut-Rank
All Tire Press +30 psi	03-Traffic-General-Axle	0.5
All Tire Press −30 psi	03-Traffic-General-Axle	0.3
Dual Tire Press +30 psi	03-Traffic-General-Axle	0.5
Dual Tire Press −30 psi	03-Traffic-General-Axle	0.3
AC Visc Grade 5	07-AC-Binder-AC-3	0.5
2nd AC G* Delta×3	07-AC-Binder-SP-1	0.0
2nd AC G* Delta/3	07-AC-Binder-SP-1	0.0
AC PG Grade 58-34	07-AC-Binder-SP-3	0.3
AC PG Grade 76-22	07-AC-Binder-SP-3	0.3
AC Air Voids +2.5%	07-AC-General	0.4
AC Dynamic Modulus Def	07-AC-Mix	0.2
AC Dynamic Modulus/1.5	07-AC-Mix	0.4

Table G-6. Dry-Cold, AC-Thick, Significant Variables - AC Rutting.

Description	Category	ACRut-rank
Local Road TTC Class 9	02-Site	0.7
Minor Arterial TTC Class 4	02-Site	2.0
AADT −2318 (20%)	03-Traffic	0.9
AADT +2318 (20%)	03-Traffic	1.1
Wander 2" LESS	03-Traffic-General	1.8
Wander 2" MORE	03-Traffic-General	2.5
Elevation −1500'	04-Climate	0.7
Elevation +1500'	04-Climate	0.7
Latitude +0.6	04-Climate	1.4
Longitude −1	04-Climate	1.5
Surf Shortwave Absorp −0.05	06-Drain	1.5
Surf Shortwave Absorp +0.05	06-Drain	1.5
AC Top Layer −1"	07-AC	1.8
Absolute Visc +200	07-AC-Binder-AC-1	0.8
AC Visc Grade 20	07-AC-Binder-AC-3	0.8
AC G* Delta×3	07-AC-Binder-SP-1	1.5
AC G* Delta/3	07-AC-Binder-SP-1	1.4
AC Air Voids −2%	07-AC-General	0.6
AC Eff Binder Content +3%	07-AC-General	0.8
AC Eff Binder Content −3%	07-AC-General	0.6
AC Heat Capacity +0.08	07-AC-General	1.8
AC Heat Capacity +0.17	07-AC-General	0.9
AC Poisson's Ratio −0.05	07-AC-General	0.8
AC Poisson's Ratio +0.05	07-AC-General	0.7
AC % Pass #200 +2%	07-AC-Mix	1.9
AC All Gradations on Hi Side	07-AC-Mix	1.7
AC Dynamic Modulus×1.5	07-AC-Mix	0.6
AC Top % Retained #4" + 6%	07-AC-Mix	1.4
AC Top % Retained #4" - 6%	07-AC-Mix	1.5
AC Top % Retained 3/8" + 7.5%	07-AC-Mix	2.3
AC Top % Retained 3/8" - 7.5%	07-AC-Mix	2.0
SG PI −10	10-SG-ICM	2.4
SG Sat Hyd Cond×10	10-SG-ICM	2.4
SG Sat Hyd Cond/10	10-SG-ICM	2.4
SG Thickness −25"	10-SG-Str	0.6

Table G-7. Dry-Cold, AC-Thick, Highly Significant Variables - Total Rutting Rank.

Description	Category	TotR-Rank
All Tire Press −30 psi	03-Traffic-General-Axle	0.4
Dual Tire Press −30 psi	03-Traffic-General-Axle	0.4
2nd AC G* Delta×3	07-AC-Binder-SP-1	0.0
2nd AC G* Delta/3	07-AC-Binder-SP-1	0.0
AC PG Grade 58-34	07-AC-Binder-SP-3	0.4
AC PG Grade 76-22	07-AC-Binder-SP-3	0.3
AC Air Voids +2.5%	07-AC-General	0.4
AC Dynamic Modulus Def	07-AC-Mix	0.2
AC Dynamic Modulus/1.5	07-AC-Mix	0.4

Table G-8. Dry-Cold, AC, Highly Significant Variables - Total Rutting Rank.

Description	Category	TotR-Rank
Local Road TTC Class 9	02-Site	0.6
Minor Arterial TTC Class 4	02-Site	1.3
AADT −2318 (20%)	03-Traffic	0.9
AADT +2318 (20%)	03-Traffic	1.1
Wander 2" LESS	03-Traffic-General	1.8
All Tire Press +30 psi	03-Traffic-General-Axle	0.6
Dual Tire Press +30 psi	03-Traffic-General-Axle	0.6
Elevation −1500'	04-Climate	0.7
Elevation +1500'	04-Climate	0.7
Latitude +0.6	04-Climate	1.3
Longitude −1	04-Climate	1.5
Water Table Depth at 1'	04-Climate	1.8
Surf Shortwave Absorp −0.05	06-Drain	1.6
Surf Shortwave Absorp +0.05	06-Drain	1.5
Absolute Visc +200	07-AC-Binder-AC-1	0.8
AC Visc Grade 20	07-AC-Binder-AC-3	0.8
AC Visc Grade 5	07-AC-Binder-AC-3	0.6
AC G* Delta×3	07-AC-Binder-SP-1	1.5
AC G* Delta/3	07-AC-Binder-SP-1	1.5
AC Air Voids −2%	07-AC-General	0.7
AC Eff Binder Content +3%	07-AC-General	0.8
AC Eff Binder Content −3%	07-AC-General	0.7
AC Heat Capacity +0.08	07-AC-General	2.0
AC Heat Capacity +0.17	07-AC-General	1.0
AC Poisson’s Ratio −0.05	07-AC-General	0.9
AC Poisson’s Ratio +0.05	07-AC-General	0.8
AC % Pass #200 +2%	07-AC-Mix	2.1
AC All Gradations on Hi Side	07-AC-Mix	1.8
AC Dynamic Modulus×1.5	07-AC-Mix	0.6
AC Top % Retained #4 +6%	07-AC-Mix	1.5
AC Top % Retained #4 −6%	07-AC-Mix	1.6
AC Top % Retained 3/8" +7.5%	07-AC-Mix	2.4
AC Top % Retained 3/8" −7.5%	07-AC-Mix	2.2
CHLS PI −2	09-CHLS-ICM	2.4
SG Resilient Modulus −5 ksi	10-SG-Str	2.4
SG Thickness −25"	10-SG-Str	1.3

Table G-9. Dry-Cold, AC-Thick, Highly Significant Variables - IRI Rank.

Description	Category	IRI-Rank
Initial IRI +12	02-Analysis	0.1
Initial IRI −13	02-Analysis	0.1
Local Road TTC Class 9	02-Site	0.5
Elevation −1500'	04-Climate	0.3
Elevation +1500'	04-Climate	0.2
Latitude +0.6	04-Climate	0.3
Water Table Depth at 1'	04-Climate	0.4
2nd AC G* Delta×3	07-AC-Binder-SP-1	0.2
2nd AC G* Delta/3	07-AC-Binder-SP-1	0.2
2nd AC Air Voids +2.5%	07-AC-General	0.2
2nd AC Air Voids −2%	07-AC-General	0.4
2nd AC Eff Binder Content +3%	07-AC-General	0.5
2nd AC Eff Binder Content −3%	07-AC-General	0.2
CHLS PI −2	09-CHLS-ICM	0.4
SG PI −10	10-SG-ICM	0.5
SG Sat Hyd Cond×10	10-SG-ICM	0.4
SG Sat Hyd Cond/10	10-SG-ICM	0.4
SG Spec Grav +0.05	10-SG-ICM	0.2
SG Resilient Modulus −5 ksi	10-SG-Str	0.4

Table G-10. Dry-Cold, AC-Thick, Significant Variables - IRI Rank.

Description	Category	IRI-Rank
Base Construction −2 month	01-General	1.0
Minor Arterial TTC Class 4	02-Site	0.8
AADT −2318 (20%)	03-Traffic	1.0
AADT +2318 (20%)	03-Traffic	1.0
Wander 2" Less	03-Traffic-General	1.6
Wander 2" More	03-Traffic-General	1.7
Longitude +1	04-Climate	2.5
Longitude −1	04-Climate	0.7
AC 2nd AC Layer +1"	07-AC	0.9
AC 2nd AC Layer −1"	07-AC	0.7
AC Top Layer +1"	07-AC	1.0
AC Top Layer −1"	07-AC	0.8
Absolute Visc +200	07-AC-Binder-AC-1	2.2
2nd AC Visc Grade 30 Deflt	07-AC-Binder-AC-3	1.6
2nd AC PG Grade 70-28	07-AC-Binder-SP-3	1.4
2nd AC PG Grade 82-16	07-AC-Binder-SP-3	2.2
AC PG Grade 76-22	07-AC-Binder-SP-3	2.2
AC Air Voids +2.5%	07-AC-General	2.5
2nd AC % Pass #200 −3%	07-AC-Mix	2.5
2nd AC All Gradations on Low Side	07-AC-Mix	2.2
2nd AC Dynamic Modulus/1.5	07-AC-Mix	0.7
2nd AC Dynamic Modulus ×1.5	07-AC-Mix	0.8
AC Dynamic Modulus Def	07-AC-Mix	0.8
AC Dynamic Modulus×1.5	07-AC-Mix	1.7
AC Dynamic Modulus/1.5	07-AC-Mix	1.6
CHLS Def Soil Water Values	09-CHLS-ICM	2.5
CHLS Low Soil Water Values	09-CHLS-ICM	1.1
CHLS P200 −10%	09-CHLS-ICM	1.9
CHLS P200 −40%	09-CHLS-ICM	1.3
CHLS PI +4	09-CHLS-ICM	0.6
CHLS Uncompacted	09-CHLS-ICM	1.7
CHLS Unit Wt −10 pcf	09-CHLS-ICM	1.9
CH Lime Stab Layer +2"	09-CHLS-Str	2.2
CH Lime Stab Layer −2"	09-CHLS-Str	1.9
CH LS Poisson’s Ratio +0.10	09-CHLS-Str	2.5
CHLS Resilient Modulus×0.7	09-CHLS-Str	1.2
CHLS Resilient Modulus×1.3	09-CHLS-Str	1.4
SG Def Soil Water Values	10-SG-ICM	1.7
SG High Soil Water Values	10-SG-ICM	1.9
SG Low Soil Water Values	10-SG-ICM	1.9
SG PI +10	10-SG-ICM	2.5
SG Sat Hyd Cond	10-SG-ICM	0.8
SG Uncompacted	10-SG-ICM	2.2
SG Unit Wt −11 pcf	10-SG-ICM	2.2
SG Resilient Modulus +5 ksi	10-SG-Str	0.8

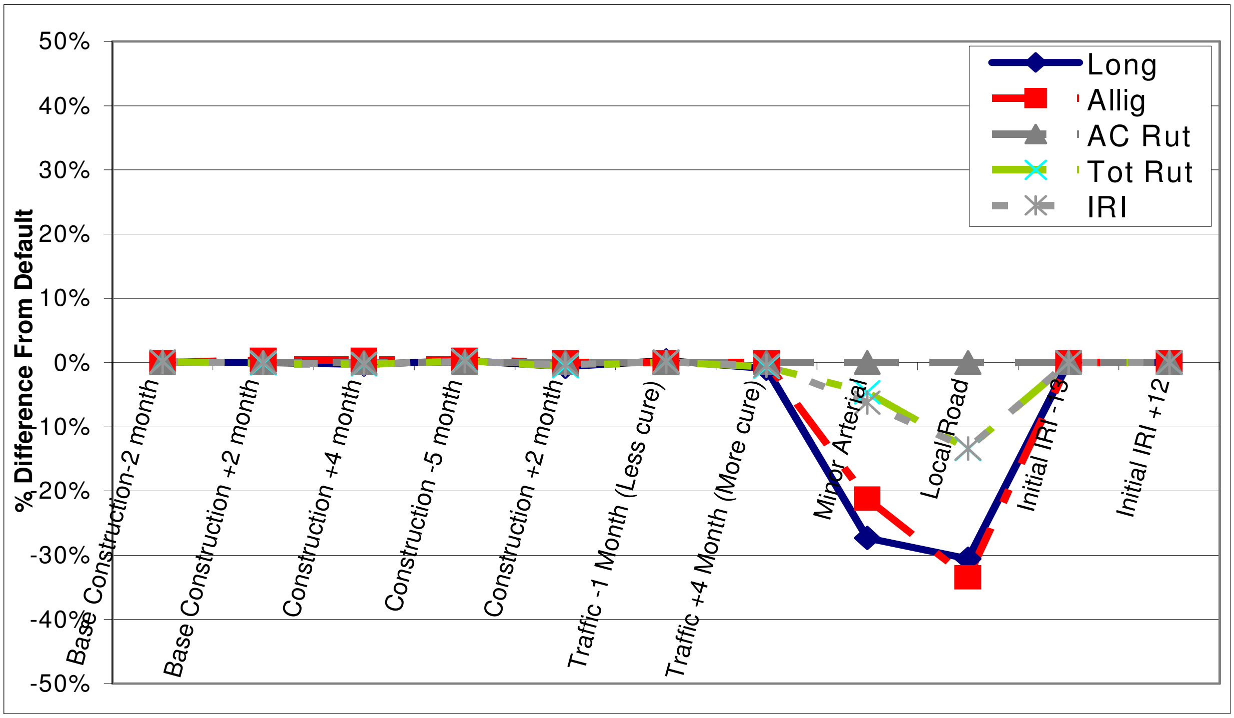

Figure G-1. Dry-Cold, AC-Thick, General Variables.

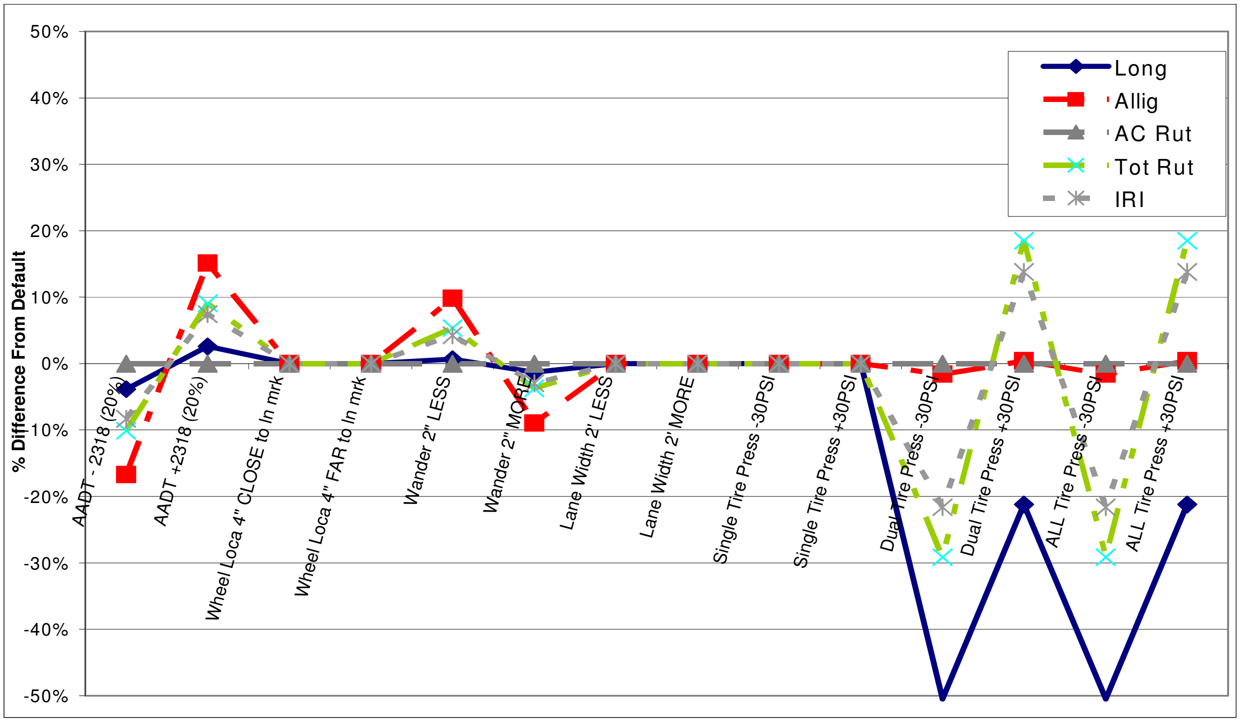

Figure G-2. Dry-Cold, AC-Thick, Traffic Variables.

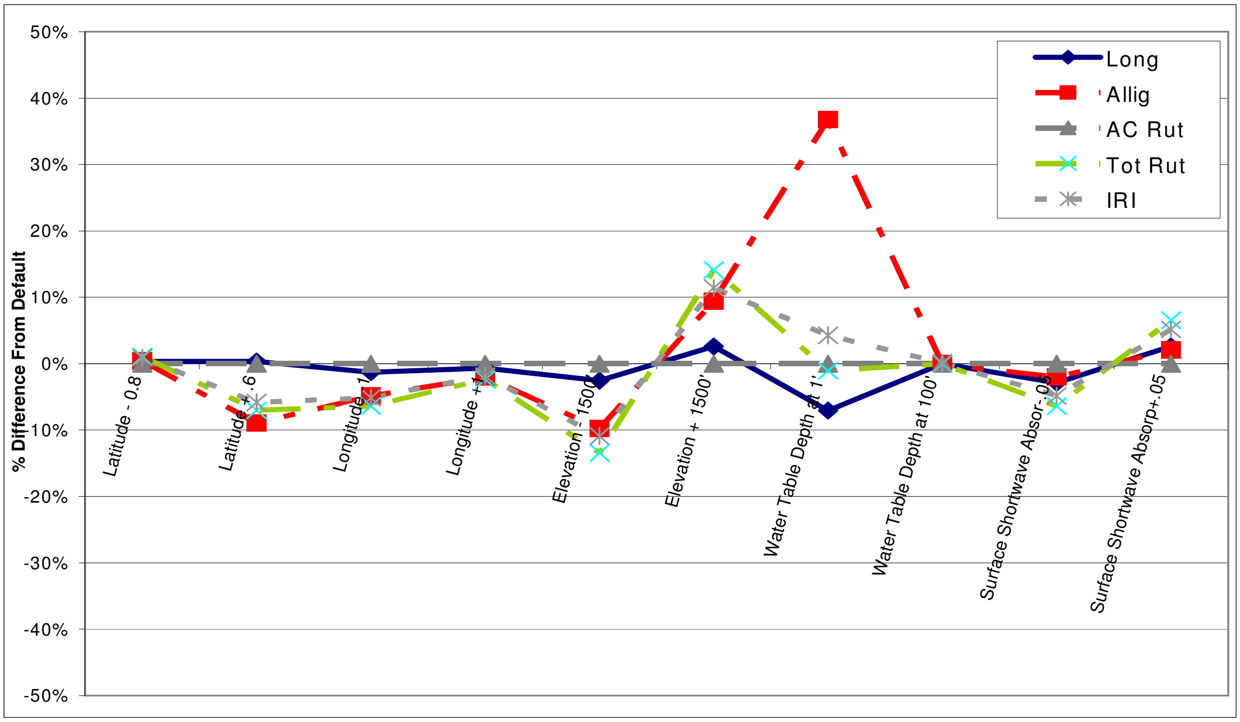

Figure G-3. Dry-Cold, AC-Thick, Climate Variables.

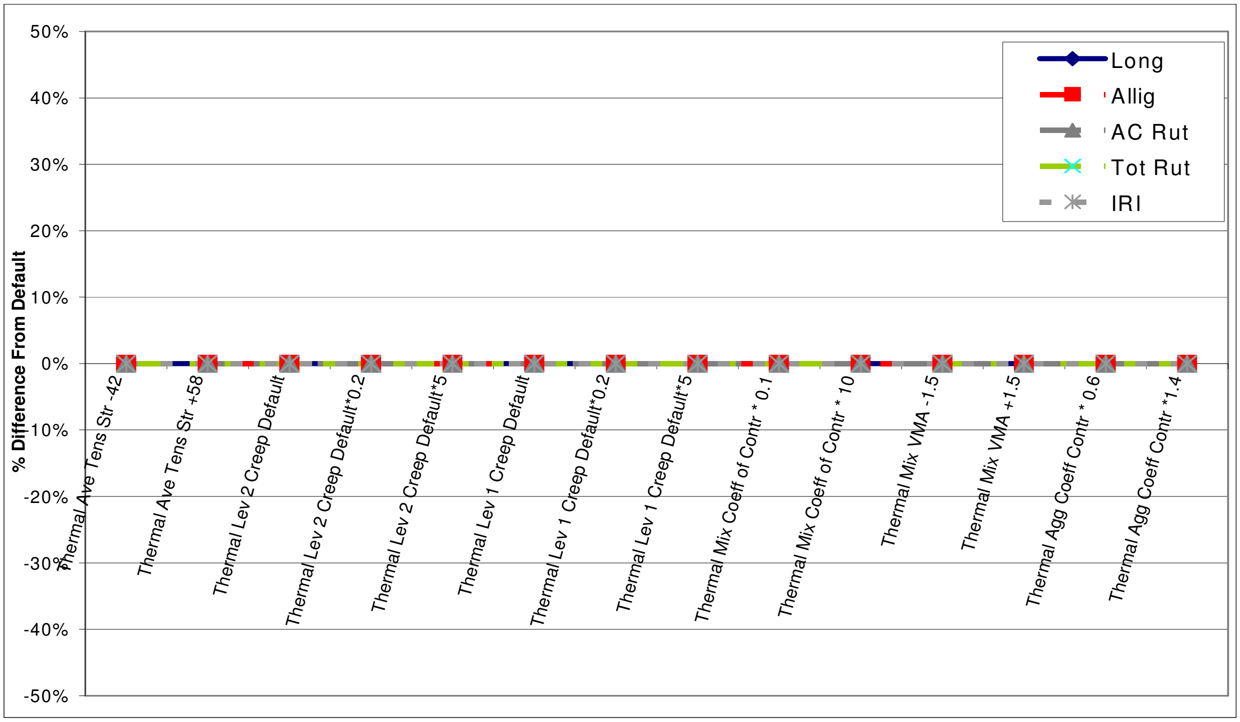

Figure G-4. Dry-Cold, AC-Thick, Thermal Variables.

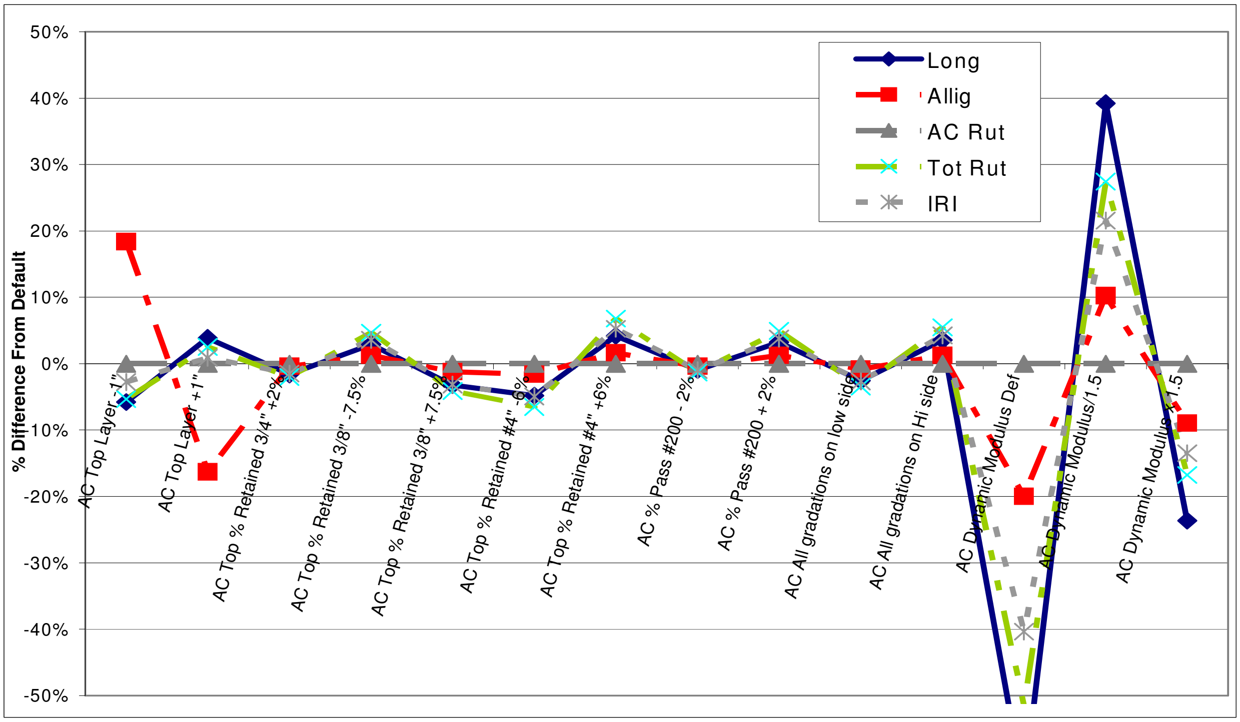

Figure G-5. Dry-Cold, AC-Thick, AC Top Mix Variables.

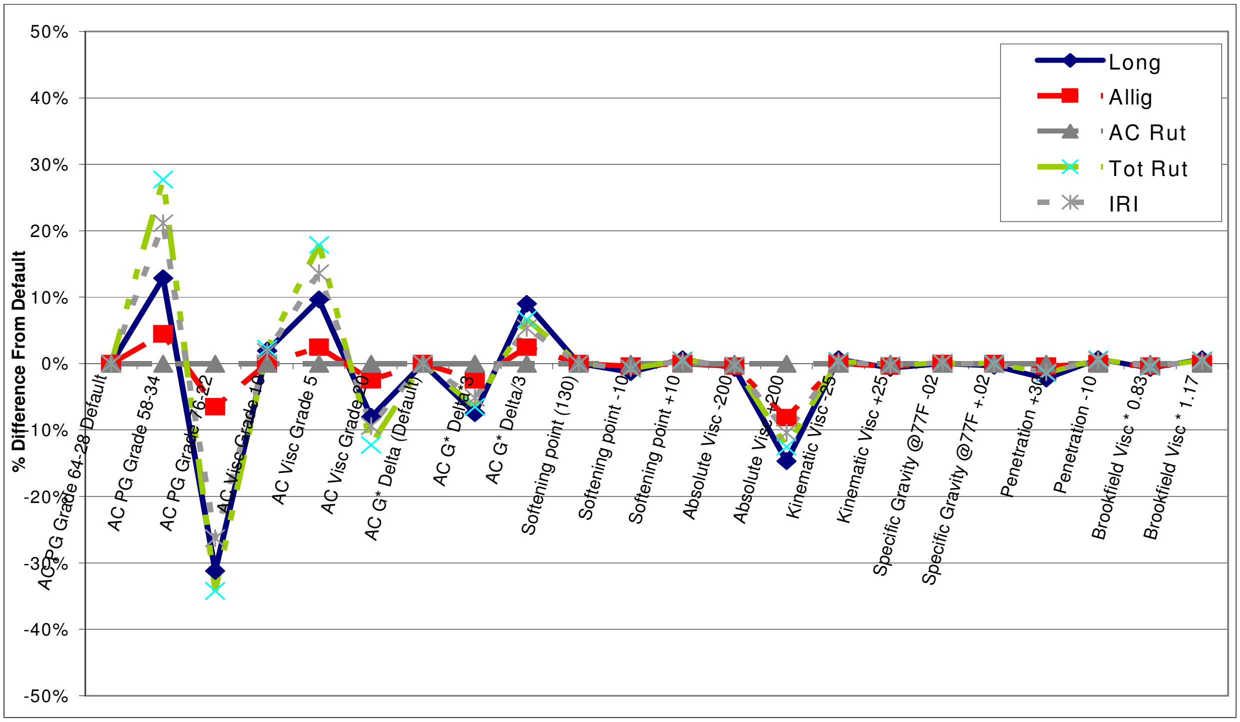

Figure G-6. Dry-Cold, AC-Thick, AC Top Layer Binder Variables.

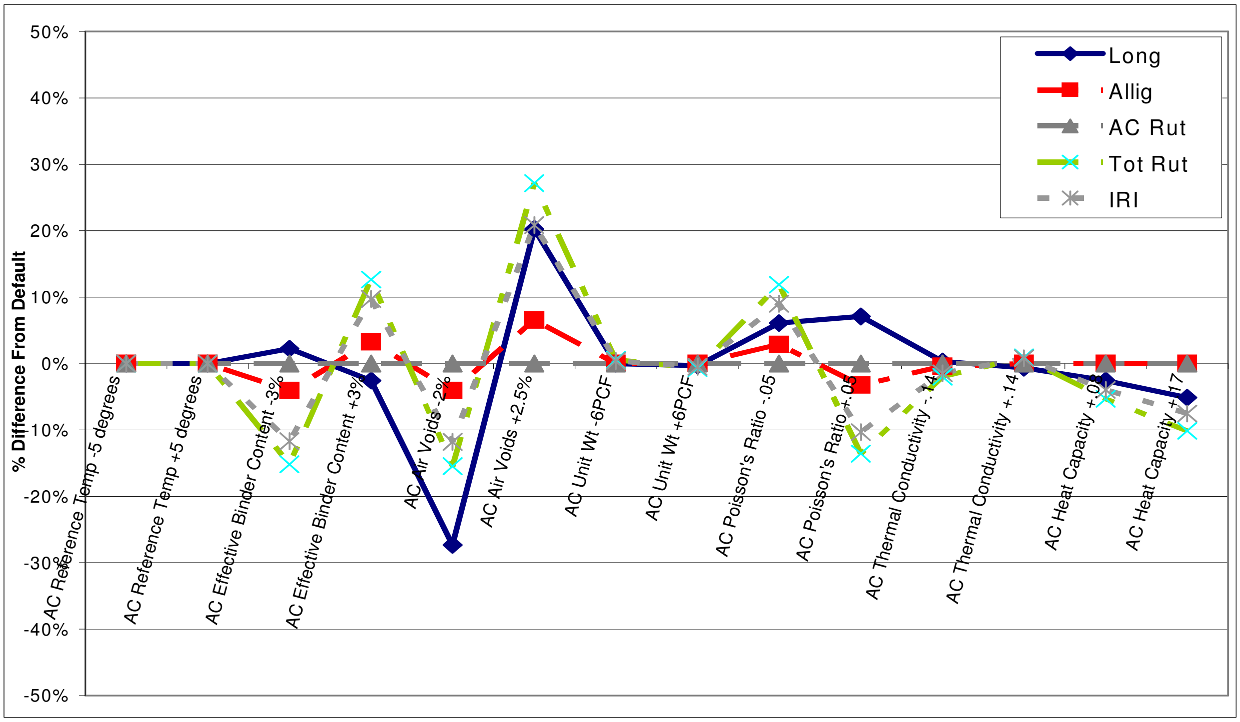

Figure G-7. Dry-Cold, AC-Thick, AC Top Layer General Variables.

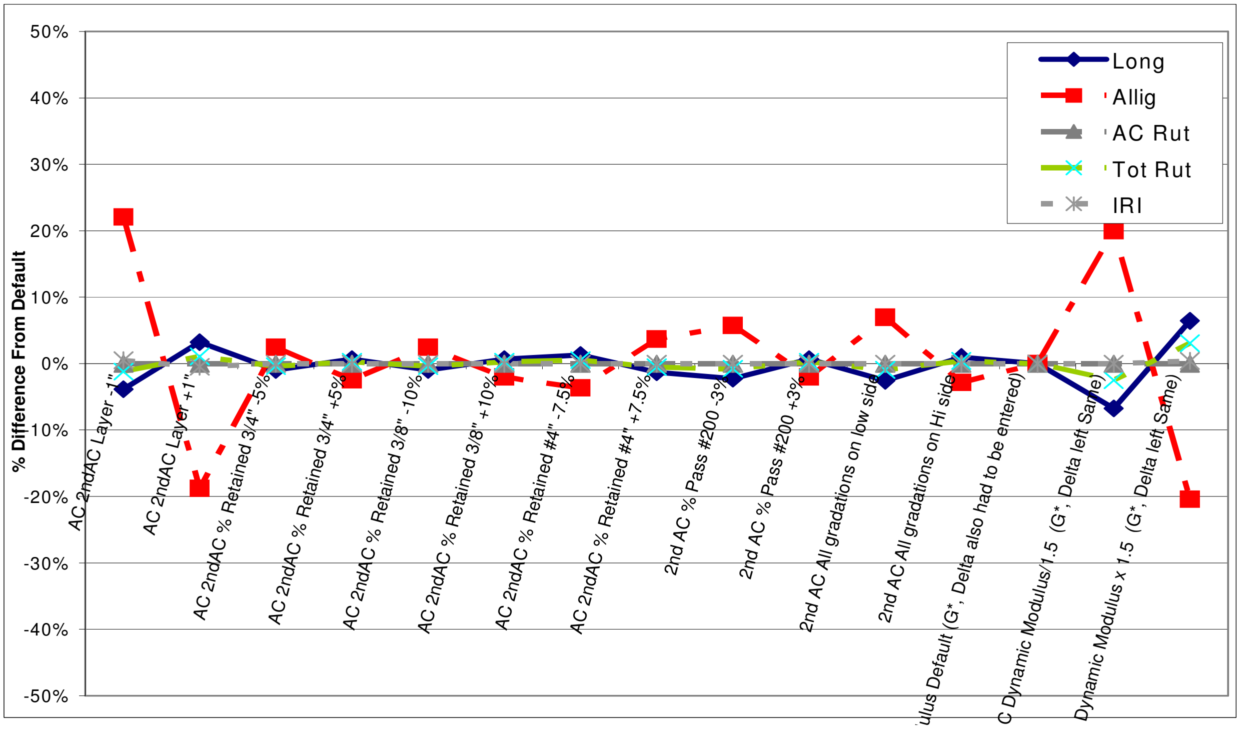

Figure G-8. Dry-Cold, AC-Thick, AC 2nd Layer Mix Variables.

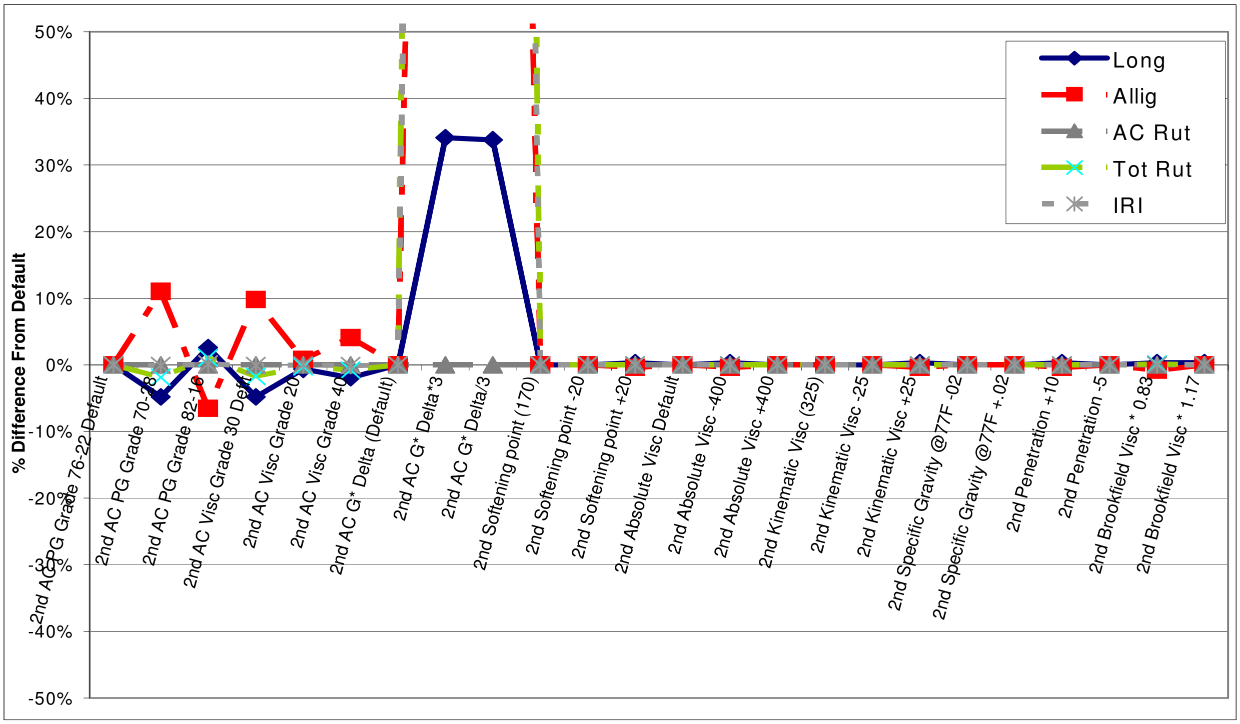

Figure G-9. Dry-Cold, AC-Thick, AC 2nd Layer Binder Variables.

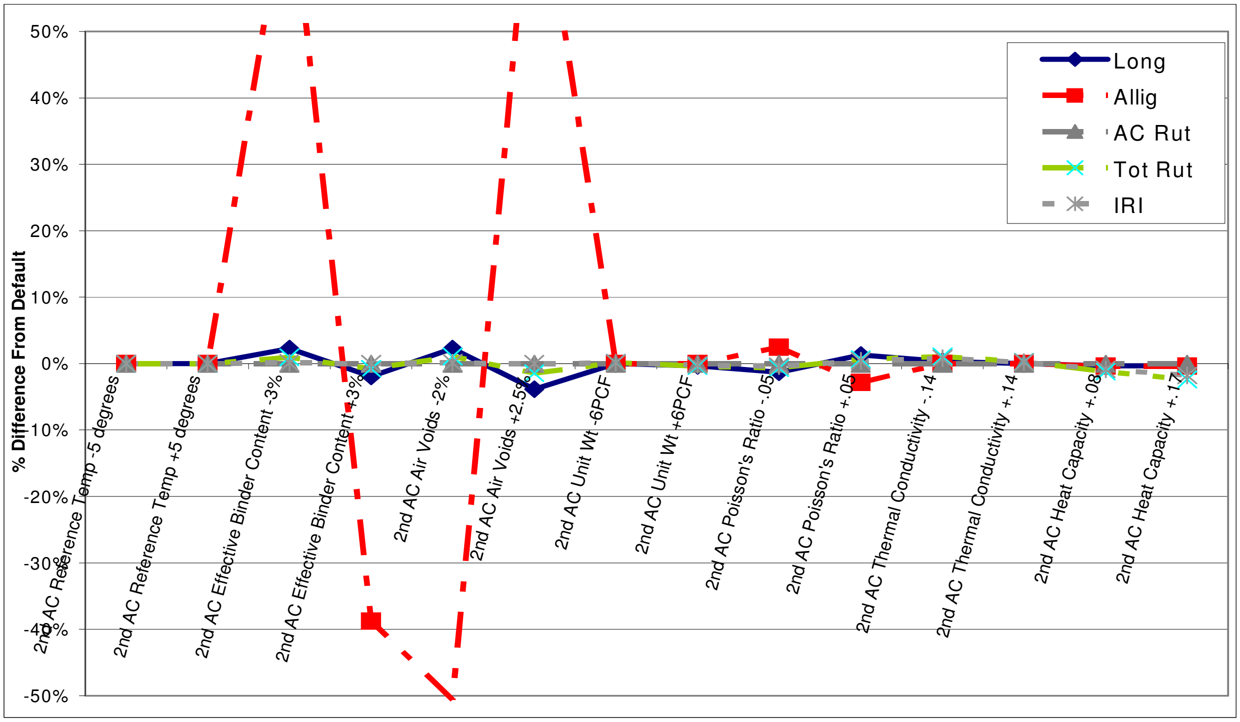

Figure G-10. Dry-Cold, AC-Thick, AC 2nd Layer General Variables.

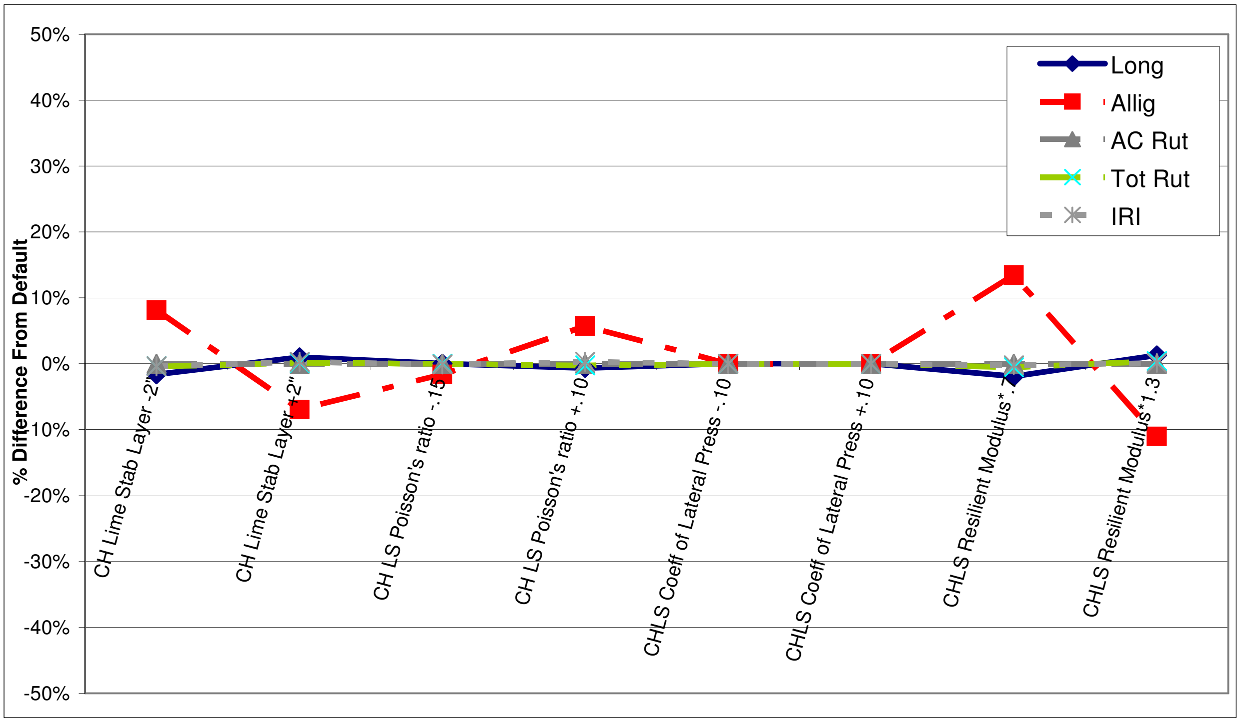

Figure G-11. Dry-Cold, AC-Thick, Lime Treated Structural Variables.

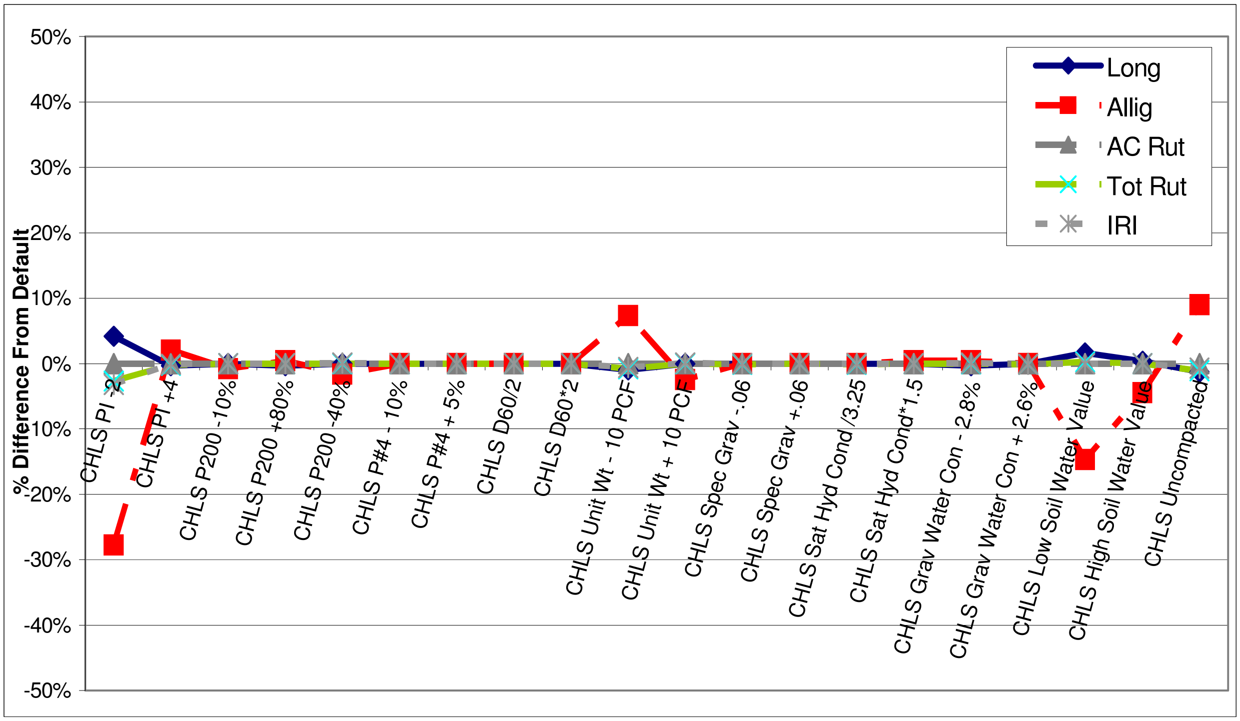

Figure G-12. Dry-Cold, AC-Thick, Lime Treated Climatic Variables.

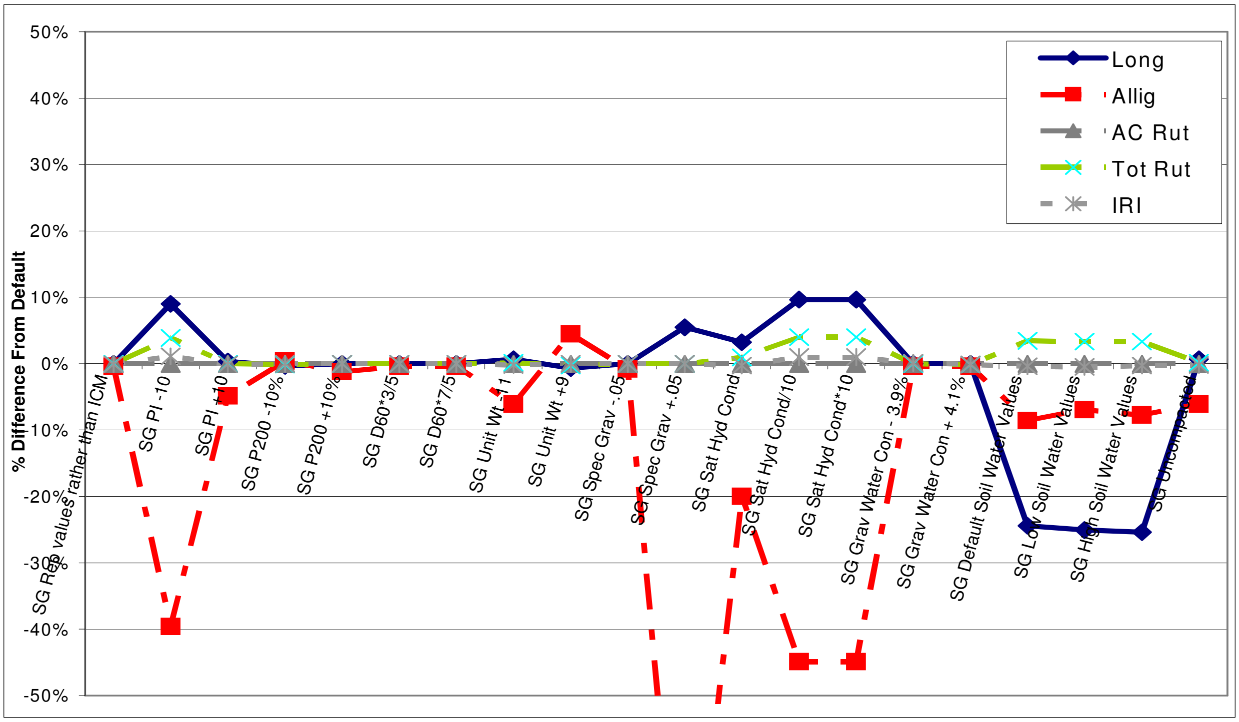

Figure G-13. Dry-Cold, AC-Thick, Subgrade Climatic Variables.

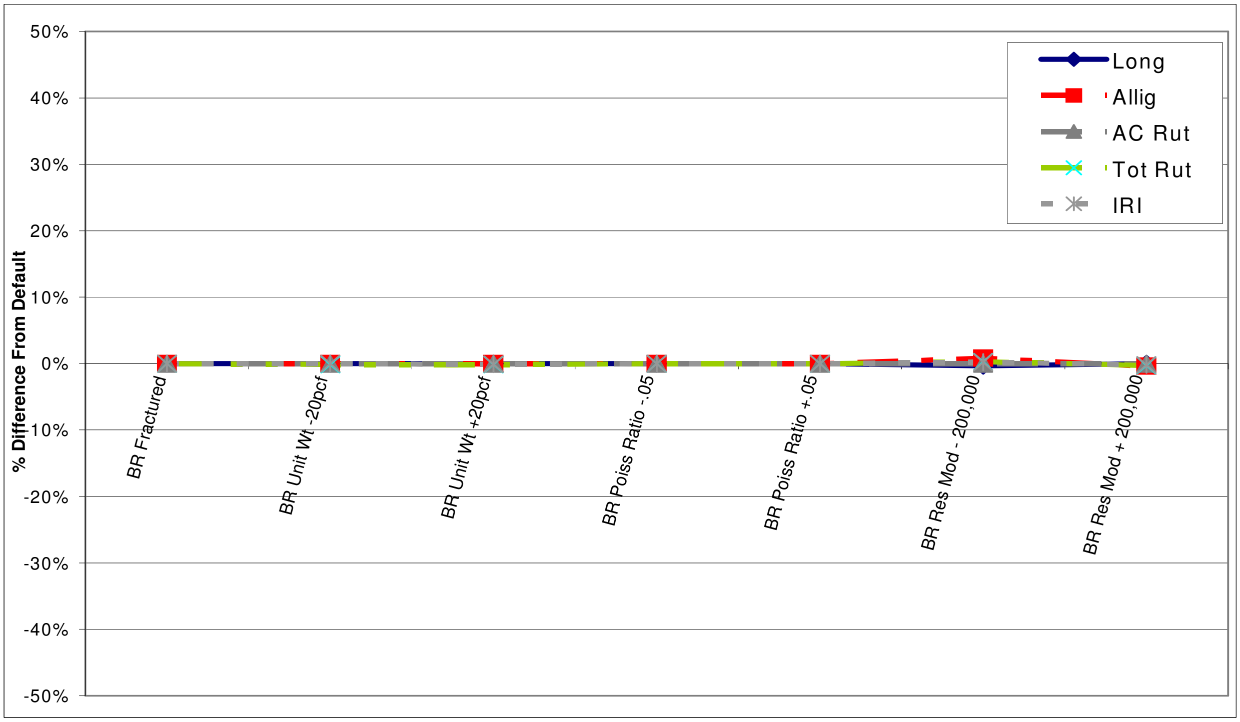

Figure G-14. Dry-Cold, AC-Thick, Bedrock Variables.

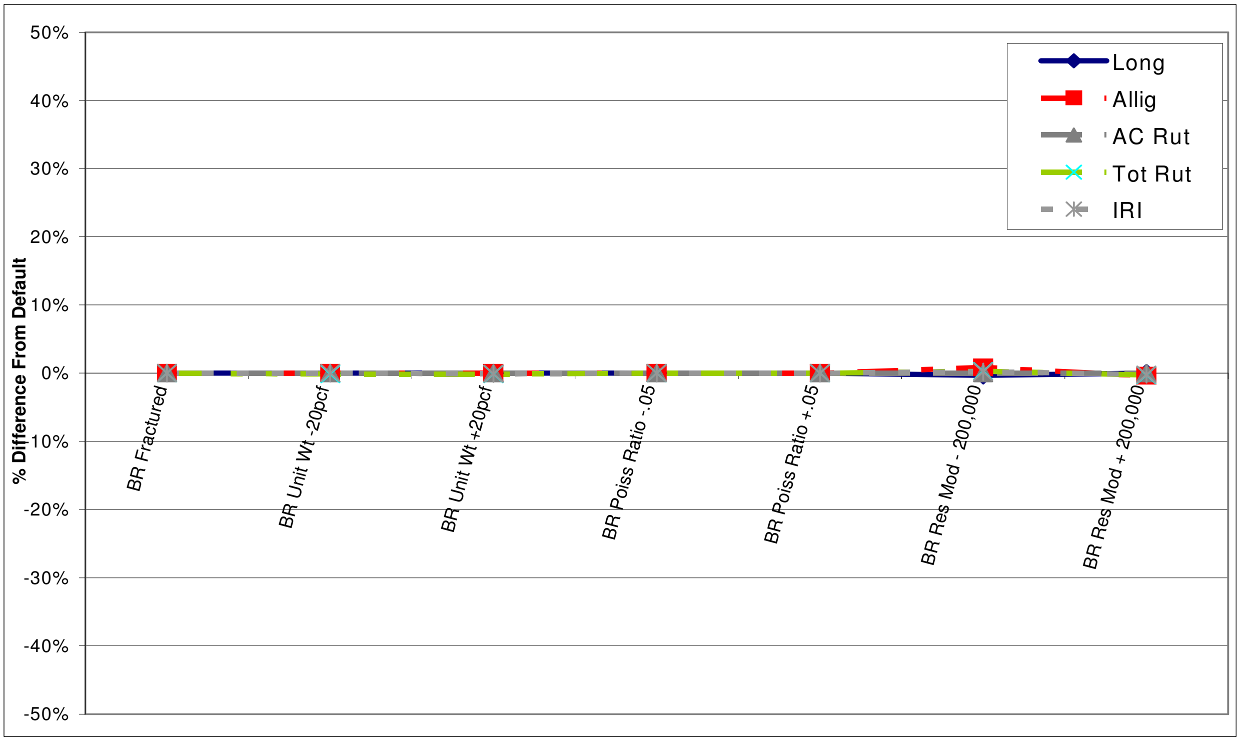

Figure G-15. Dry-Cold, AC-Thick, Bedrock Variables.

Table G-11. Results of Dry-Cold, AC-Thick, General Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	Tot Rut Rank	IRI Rank
Base Construction −2 month	=	=	>	>	> >
Base Construction +2 month	=	>	<	=	<
Construction +2 month	<	=	<	<	=
Construction +4 month	<	>	<	<	=
Construction −5 month	>	>	>	>	=
Traffic +4 month	<	=	<	<	<
Traffic −1 month	>	=	>	>	<
Initial IRI +12	=	=	=	=	> > >
Initial IRI −13	=	=	=	=	< < <
Local Road TTC Class 9	< < <	< < <	< <	< <	< < <
Minor Arterial TTC Class 4	< < <	< <	< <	< <	< <

Table G-12. Results of Dry-Cold, AC-Thick, Traffic Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	Tot Rut Rank	IRI Rank
AADT −2318 (20%)	< <	< <	< <	< <	< <
AADT +2318 (20%)	> >	> >	> >	> >	> >
Lane Width 2' Less	=	=	=	=	=
Lane Width 2' More	=	=	=	=	=
Wander 2" Less	>	> >	> >	> >	> >
Wander 2" More	< <	< <	<	<	< <
Wheel Loca 4" Closer	=	=	=	=	=
Wheel Loca 4" Far to Ln	=	=	=	=	=
All Tire Press +30 psi	< < <	>	> > >	> >	=
All Tire Press −30 psi	< < <	<	< < <	< < <	<
Dual Tire Press +30 psi	< < <	>	> > >	> >	=
Dual Tire Press −30 psi	< < <	<	< < <	< < <	<
Single Tire Press +30 psi	=	=	=	=	=
Single Tire Press −30 psi	=	=	=	=	=

Table G-13. Results of Dry-Cold, AC-Thick, Climate Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
Elevation −1500'	< <	< <	< <	< <	> > >
Elevation +1500'	> >	> >	> >	> >	< < <
Latitude −0.8	>	>	>	>	<
Latitude +0.6	>	< <	< <	< <	> > >
Longitude +1	<	<	<	<	> >
Longitude −1	< <	<	< <	< <	> >
Water Table Depth at 1'	< < <	> > >	<	> >	> > >
Water Table Depth at 100'	=	=	=	>	=
Surf Shortwave Absorp −0.05	< <	<	< <	< <	<
Surf Shortwave Absorp +0.05	> >	>	> >	> >	>

Table G-14. Results of Dry-Cold, AC-Thick, AC Thermal Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	Tot Rut Rank	IRI Rank
Thermal Agg Coeff Contr×0.6	=	=	=	=	=
Thermal Agg Coeff Contr ×1.4	=	=	=	=	=
Thermal Ave Tens Str +58	=	=	=	=	=
Thermal Ave Tens Str −42	=	=	=	=	=
Thermal Lev 1 Creep Def	=	=	=	=	=
Thermal Lev 1 Creep Def×0.2	=	=	=	=	=
Thermal Lev 1 Creep Def×5	=	=	=	=	=
Thermal Lev 2 Creep Def	=	=	=	=	=
Thermal Lev 2 Creep Def×0.2	=	=	=	=	=
Thermal Lev 2 Creep Def×5	=	=	=	=	=
Thermal Mix Coeff Contr×0.1	=	=	=	=	=
Thermal Mix Coeff Contr×10	=	=	=	=	=
Thermal Mix VMA +1.5%	=	=	=	=	=
Thermal Mix VMA −1.5%	=	=	=	=	=

Table G-15. Results of Dry-Cold, AC-Thick, AC Binder Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
AC 1st AC Layer +1"	> >	< <	>	>	< <
AC 1st AC Layer −1"	< < <	> >	< <	<	> >
AC 2nd AC Layer +1"	> >	< <	>	<	< <
AC 2nd AC Layer −1"	< <	> >	<	>	> >
1st AC Absolute Visc +200	< < <	< <	< <	< <	< <
1st AC Absolute Visc −200	<	<	<	<	=
1st AC Brookfield Visc×0.83	<	<	<	<	=
1st AC Brookfield Visc×1.17	>	=	>	>	=
1st AC Kinematic Visc +25	<	<	<	<	=
1st AC Kinematic Visc −25	>	=	>	>	=
1st AC Penetration +30	< <	<	<	<	=
1st AC Penetration −10	>	=	>	>	=
1st AC Softening Point (130)	=	=	=	=	=
1st AC Softening Point +10	>	=	>	>	=
1st AC Softening Point −10	< <	<	<	<	=
1st AC Spec Grav @77F +0.02	<	=	=	<	=
1st AC Spec Grav @77F −0.02	=	=	>	>	=
2nd Absolute Visc +400	=	=	=	=	=
2nd Absolute Visc −400	>	<	=	=	=
2nd Absolute Visc Default	=	=	=	=	=
2nd Brookfield Visc×0.83	>	<	>	=	<
2nd Brookfield Visc×1.17	>	=	=	=	=
2nd Kinematic Visc (325)	=	=	=	=	=
2nd Kinematic Visc +25	>	<	=	=	=
2nd Kinematic Visc −25	=	=	=	=	=
2nd Penetration +10	>	<	=	=	<
2nd Penetration −5	=	=	=	=	=
2nd Softening Point (170)	=	=	=	=	=
2nd Softening Point +20	>	<	=	=	<
2nd Softening Point −20	=	=	=	=	=
2nd Spec Grav @77F +0.02	=	=	=	=	=
2nd Spec Grav @77F −0.02	=	=	=	=	=

Table G-15. Results of Dry-Cold, AC-Thick, AC Binder Variables (Continued).

1st AC Visc Grade 10	> >	=	>	>	<
1st AC Visc Grade 20	< < <	<	< <	< <	<
1st AC Visc Grade 5	> > >	>	> > >	> >	>
2nd AC Visc Grade 20	<	>	<	=	=
2nd AC Visc Grade 30 Deflt	< <	> >	<	<	> >
2nd AC Visc Grade 40	< <	>	<	<	>
1st AC G* Delta (Def)	=	=	=	=	=
1st AC G* Delta×3	< < <	<	< <	< <	<
1st AC G* Delta/3	> > >	>	> >	> >	>
2nd AC G* Delta (Def)	=	=	=	=	=
2nd AC G* Delta×3	> > >	> > >	> > >	> > >	< < <
2nd AC G* Delta/3	> > >	> > >	> > >	> > >	< < <
1st AC PG Grade 58-34	> > >	>	> > >	> > >	>
1st AC PG Grade 64-28 Def	=	=	=	=	=
1st AC PG Grade 76-22	< < <	< <	< < <	< < <	< <
2nd AC PG Grade 70-28	< <	> >	<	<	> >
2nd AC PG Grade 76-22 Def	=	=	=	=	=
2nd AC PG Grade 82-16	> >	< <	>	>	< <

Table G-16. Results of Dry-Cold, AC-Thick, General AC Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
1st AC Air Voids +2.5%	> > >	> >	> > >	> > >	> >
1st AC Air Voids −2%	< < <	<	< <	< <	<
1st AC Eff Binder Cont +3%	< <	>	> >	> >	>
1st AC Eff Binder Cont −3%	> >	<	< <	< <	<
1st AC Heat Capacity +0.08	< <	=	< <	< <	<
1st AC Heat Capacity +0.17	< <	=	< <	< <	<
1st AC Poisson’s Ratio −0.05	> > >	>	> >	> >	>
1st AC Poisson’s Ratio +0.05	> > >	<	< <	< <	<
1st AC Ref Temp +5 °F	=	=	=	=	=
1st AC Ref Temp −5 °F	=	=	=	=	=
1st AC Thermal Conduct −0.14	>	<	<	<	<
1st AC Thermal Conduct +0.14	<	=	>	>	<
1st AC Unit Wt +6 pcf	<	=	<	<	=
1st AC Unit Wt −6 pcf	=	=	>	>	=
2nd AC Air Voids +2.5%	< <	> > >	<	=	> > >
2nd AC Air Voids −2%	> >	< < <	>	>	< < <
2nd AC Eff Binder Content +3%	< <	< < <	<	=	< < <
2nd AC Eff Binder Content −3%	> >	> > >	>	>	> > >
2nd AC Heat Capacity +0.08	<	<	<	<	<
2nd AC Heat Capacity +0.17	<	<	<	<	<
2nd AC Poisson’s Ratio −0.05	< <	>	<	<	>
2nd AC Poisson’s Ratio +0.05	> >	<	>	>	<
2nd AC Reference Temp +5 °F	=	=	=	=	=
2nd AC Reference Temp −5 °F	=	=	=	=	=
2nd AC Thermal Conduct −0.14	>	=	>	>	<
2nd AC Thermal Conduct +0.14	=	=	>	>	=
2nd AC Unit Wt +6 pcf	<	=	<	<	<
2nd AC Unit Wt −6 pcf	=	=	>	>	<

Table G-17. Results of Dry-Cold, AC-Thick, AC Mix Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
1st AC % Pass #200 −2%	<	<	<	<	<
1st AC % Pass #200 +2%	> >	>	> >	> >	>
1st AC % Retained #4 +6%	> >	>	> >	> >	>
1st AC % Retained #4 −6%	< <	<	< <	< <	<
1st AC % Retained 3/4" +2%	< <	<	<	<	<
1st AC % Retained 3/8" +7.5%	< <	<	< <	< <	<
1st AC % Retained 3/8" −7.5%	> >	>	> >	> >	>
1st AC All Gradations Hi	> >	>	> >	> >	>
1st AC All Gradations low	< <	<	<	<	<
1st AC Dynamic Mod Def	< < <	< <	< < <	< < <	< <
1st AC Dynamic Mod/1.5	> > >	> >	> > >	> > >	> >
1st AC Dynamic Mod×1.5	< < <	< <	< <	< <	< <
2nd AC % Pass #200 +3%	>	<	>	=	<
2nd AC % Pass #200 −3%	< <	>	<	=	> >
2nd AC All Gradations Hi	>	<	>	=	<
2nd AC All Gradations low	< <	> >	<	=	> >
2nd AC Dynamic Mod Def	=	=	=	=	=
2nd AC Dynamic Mod/1.5	< < <	> >	<	=	> >
2nd AC % Retained #4 +7.5%	< <	>	<	=	>
2nd AC % Retained #4 −7.5%	> >	<	>	=	<
2nd AC % Retained 3/4" +5%	>	<	>	=	<
2nd AC % Retained 3/4" −5%	<	>	<	=	>
2nd AC % Retained 3/8" +10%	>	<	>	=	<
2nd AC % Retained 3/8" −10%	<	>	<	=	>
2nd AC Dynamic Mod×1.5	> > >	< <	>	>	< <

Table G-18. Results of Dry-Cold, AC-Thick, Lime Treated ICM Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
CHLS D60*2	=	=	=	=	=
CHLS D60/2	=	=	=	=	=
CHLS Def Soil Water Value	>	<	>	=	<<
CHLS Grav Water Con −2.8%	<	>	=	>	=
CHLS Grav Water Con - Default	=	=	=	=	<
CHLS Grav Water Con +2.6%	=	=	<	<	<
CHLS High Soil Water Value	>	<	=	=	<
CHLS Low Soil Water Value	>>	<<	>	=	<<
CHLS P#4 −10%	=	=	=	=	=
CHLS P#4 +5%	=	=	=	=	=
CHLS P200 +80%	<	>	=	=	>
CHLS P200 −10%	=	<	=	=	<<
CHLS P200 −40%	=	<	=	>	<<
CHLS PI +4	<	>	<	<	>>
CHLS PI −2	>>	<<	<	<<	<<<
CHLS Sat Hyd Cond - Def	=	=	=	=	=
CHLS Sat Hyd Cond/3.25	=	=	<	=	=
CHLS Sat Hyd Cond×1.5	=	>	=	=	=
CHLS Soil Water Value (Prog Def)	=	=	=	=	=
CHLS Spec Grav - Def	=	=	=	=	<
CHLS Spec Grav −0.06	=	=	<	=	=
CHLS Spec Grav +0.06	=	=	=	=	<
CHLS Uncompacted	<<	>>	<	<	>>
CHLS Unit Wt −10 pcf	<	>>	<	<	>>
CHLS Unit Wt - Def	=	=	=	=	=
CHLS Unit Wt +10 pcf	=	<	=	>	<

Table G-19. Results of Dry-Cold, AC-Thick, Lime Treated Strength Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
CH Lime Stab Layer +2"	>	<<	>	>	<<
CH Lime Stab Layer −2"	<<	>>	<	<	>>
CH LS Poisson's Ratio −0.15	=	<	=	<	<
CH LS Poisson's Ratio +0.10	<	>	<	>	>>
CHLS Coeff of Lateral Press −0.10	=	=	=	=	=
CHLS Coeff of Lateral Press +0.10	=	=	=	=	=
CHLS Resilient Mod×0.7	<<	>>	<	<	>>
CHLS Resilient Mod×1.3	>>	<<	>	>	<<

Table G-20. Results of Dry-Cold, AC-Thick, Subgrade ICM Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
SG D60*3/5	=	<	=	=	<
SG D60*7/5	=	<	=	=	<
SG Def Soil Water Value	<<<	<<	>	<	<<
SG Grav Water Con −3.9%	=	<	=	>	<
SG Grav Water Con - Def	=	<	=	>	<
SG Grav Water Con +4.1%	=	<	<	<	<
SG High Soil Water Value	<<<	<<	>	<	<<
SG Low Soil Water Value	<<<	<<	>	<	<<
SG P200 +10%	=	<	=	=	<
SG P200 −10%	<	>	<	=	=
SG PI +10	>	<	=	<	<<
SG PI −10	>>>	<<<	>>	>	<<<
SG Rep Values (no ICM)	=	<	=	<	<
SG Sat Hyd Cond	>>	<<	>	<	<<
SG Sat Hyd Cond (Prog Def)	=	=	=	=	=
SG Sat Hyd Cond (Prog Def)×0.1	=	>	=	=	=
SG Sat Hyd Cond (Prog Def)×10	=	<	=	>	<
SG Sat Hyd Cond×10	>>>	<<<	>>	>	<<<
SG Sat Hyd Cond/10	>>>	<<<	>>	>	<<<
SG Soil Water Value (Prog Def)	=	<	=	=	<
SG Spec Grav - Def	=	<	=	=	<
SG Spec Grav −0.05	=	<	=	=	<
SG Spec Grav +0.05	>>	<<<	=	=	<<<
SG Uncompacted	>	<	>	<	<<
SG Unit Wt +9 pcf	<	>	<	=	>
SG Unit Wt −11 pcf	>	<	>	<	<<
SG Unit Wt - Default	=	<	=	=	<

Table G-21. Results of Dry-Cold, AC-Thick, Subgrade Strength Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
SG Coeff of Lateral Press −0.10	=	<	=	=	<
SG Coeff of Lateral Press +0.10	=	<	=	=	<
SG Poisson’s Ratio −0.05	<	<	<	>	<
SG Poisson’s Ratio +0.05	>	=	>	<	<
SG Resilient Modulus +5 ksi	> >	< <	>	>	< <
SG Resilient Modulus −5 ksi	< < <	> > >	<	> >	> > >
SG Thickness +25"	< <	>	<	>	>
SG Thickness −25"	< <	<	> >	> >	<

Table G-22. Results of Dry-Cold, AC-Thick, Bedrock Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
BR Fractured	=	=	=	=	=
BR Poiss Ratio −0.05	=	=	=	=	<
BR Poiss Ratio +0.05	=	=	=	=	=
BR Res Mod −200,000	<	>	>	>	=
BR Res Mod +200,000	=	<	<	<	<
BR Unit Wt +20 pcf	=	=	<	<	<
BR Unit Wt −20 pcf	=	=	<	=	=

APPENDIX H

WET-WARM, AC THICK RESULTS

Table H-1. Wet-Warm, AC-Thick, Highly Significant Variables - Longitudinal Cracking.

Description	Category	Long-Rank
Local Road TTC Class 9	02-Site	0.1
Minor Arterial TTC Class 4	02-Site	0.1
ALL Tire Press +30 psi	03-Traffic-General-Axle	0.2
ALL Tire Press −30 psi	03-Traffic-General-Axle	0.1
Dual Tire Press +30 psi	03-Traffic-General-Axle	0.2
Dual Tire Press −30 psi	03-Traffic-General-Axle	0.1
Water Table Depth at 1'	04-Climate	0.4
AC 2nd AC Layer +1"	07-AC	0.5
AC 2nd AC Layer −1"	07-AC	0.4
AC Top Layer −1"	07-AC	0.4
2nd Absolute Visc Default	07-AC-Binder-AC-1	0.1
2nd Kinematic Visc (325)	07-AC-Binder-AC-1	0.1
Softening Point (170)	07-AC-Binder-AC-1	0.1
2nd AC Visc Grade 20 (Deflt)	07-AC-Binder-AC-3	0.3
2nd AC Visc Grade 30	07-AC-Binder-AC-3	0.5
AC Visc Grade 20 Softer	07-AC-Binder-AC-3	0.3
AC G* Delta×3	07-AC-Binder-SP-1	0.2
AC G* Delta/3	07-AC-Binder-SP-1	0.1
2nd AC PG Grade 76-22 Default	07-AC-Binder-SP-3	0.1
AC PG Grade 64-28	07-AC-Binder-SP-3	0.2
AC PG Grade 76-22	07-AC-Binder-SP-3	0.2
2nd AC Air Voids +2.5%	07-AC-General	0.4
AC Air Voids +2.5%	07-AC-General	0.1
AC Air Voids −2%	07-AC-General	0.1
AC Heat Capacity +0.17	07-AC-General	0.5
AC Poisson’s Ratio −0.05	07-AC-General	0.3
AC Poisson’s Ratio +0.05	07-AC-General	0.2
2nd AC Dynamic Modulus/1.5	07-AC-Mix	0.2
2ndAC Dynamic Modulus×1.5	07-AC-Mix	0.2
AC Dynamic Modulus Default	07-AC-Mix	0.2
AC Dynamic Modulus×1.5	07-AC-Mix	0.1
AC Dynamic Modulus/1.5	07-AC-Mix	0.0
CHLS PI −2	09-CHLS-ICM	0.4
SG Default Soil Water Values	10-SG-ICM	0.2
SG High Soil Water Values	10-SG-ICM	0.2
SG Low Soil Water Values	10-SG-ICM	0.2
SG Resilient Modulus +4 ksi	10-SG-Str	0.4
SG Resilient Modulus −2 ksi	10-SG-Str	0.5
SG Thickness −25"	10-SG-Str	0.3
BR Deleted	11-BR	0.2

Table H-2. Wet-Warm, AC-Thick, Significant Variables - Longitudinal Cracking.

Description	Category	Long-Rank
Traffic +4 month (More Cure Before Traffic)	01-General	1.8
Traffic −1 month (Less Cure Before Traffic)	01-General	1.8
AADT −2318 (20%)	03-Traffic	0.9
AADT +2318 (20%)	03-Traffic	1.1
Latitude −1.1	04-Climate	1.6
Longitude +0.7	04-Climate	1.4
Surface Shortwave Absorptivity −0.05	06-Drain	0.9
Surface Shortwave Absorptivity +0.05	06-Drain	0.9
AC Top Layer +1"	07-AC	0.5
Brookfield Visc×0.83	07-AC-Binder-AC-1	2.0
Penetration +10	07-AC-Binder-AC-1	1.9
Softening Point +10	07-AC-Binder-AC-1	1.5
2nd AC Visc Grade 40	07-AC-Binder-AC-3	0.7
AC Visc Grade 30 Base	07-AC-Binder-AC-3	0.9
AC Visc Grade 40 Stiffer	07-AC-Binder-AC-3	2.4
2nd AC G* Delta (Default)	07-AC-Binder-SP-1	1.1
2nd AC G* Delta×3	07-AC-Binder-SP-1	2.3
2nd AC PG Grade 70-22	07-AC-Binder-SP-3	0.5
2nd AC PG Grade 82-22	07-AC-Binder-SP-3	0.6
2nd AC Air Voids −2%	07-AC-General	0.6
2nd AC Effective Binder Content +3%	07-AC-General	0.8
2nd AC Effective Binder Content −3%	07-AC-General	0.6
2nd AC Poisson’s Ratio −0.05	07-AC-General	1.8
2nd AC Poisson’s Ratio +0.05	07-AC-General	1.5
AC Effective Binder Content −3%	07-AC-General	1.6
AC Heat Capacity +0.08	07-AC-General	0.9
2nd AC % Pass #200 +3%	07-AC-Mix	1.8
2nd AC % Pass #200 −3%	07-AC-Mix	0.7
2nd AC All Gradations on Hi Side	07-AC-Mix	1.5
2nd AC All Gradations on Low Side	07-AC-Mix	0.7
2nd AC Dynamic Modulus Default	07-AC-Mix	1.1
AC % Pass #200 −2%	07-AC-Mix	2.4
AC % Pass #200 +2%	07-AC-Mix	0.7
AC 2ndAC % Retained #4 +7.5%	07-AC-Mix	1.1
AC 2ndAC % Retained #4 −7.5%	07-AC-Mix	1.1
AC 2ndAC % Retained 3/4" +5%	07-AC-Mix	1.8
AC 2ndAC % Retained 3/4" −5%	07-AC-Mix	1.8
AC 2ndAC % Retained 3/8" +10%	07-AC-Mix	2.1
AC 2ndAC % Retained 3/8" −10%	07-AC-Mix	1.8
AC All Gradations on Hi Side	07-AC-Mix	0.7

Table H-2. Wet-Warm, AC-Thick, Significant Variables - Longitudinal Cracking (Continued).

AC All Gradations on Low Side	07-AC-Mix	1.0
AC Top % Retained #4" +6%	07-AC-Mix	0.5
AC Top % Retained #4" −6%	07-AC-Mix	0.5
AC Top % Retained 3/4" +2%	07-AC-Mix	1.6
AC Top % Retained 3/8" +7.5%	07-AC-Mix	0.8
AC Top % Retained 3/8" −7.5%	07-AC-Mix	0.7
CHLS Default Soil Water Values	09-CHLS-ICM	1.4
CHLS P200 −10%	09-CHLS-ICM	1.0
CHLS Uncompacted	09-CHLS-ICM	2.4
CHLS Unit Wt −12 pcf	09-CHLS-ICM	2.4
CH Lime Stab Layer +2"	09-CHLS-Str	1.4
CH Lime Stab Layer −2"	09-CHLS-Str	1.1
CHLS Resilient Modulus×0.7	09-CHLS-Str	1.1
CHLS Resilient Modulus×1.3	09-CHLS-Str	1.2
SG Rep Values rather than ICM	10-SG-ICM	1.6
SG Sat Hyd Cond/100	10-SG-ICM	0.9
SG Thickness +25"	10-SG-Str	1.6

Table H-3. Wet-Warm, AC-Thick, Highly Significant Variables - Alligator Cracking.

Description	Category	Allig-Rank
Local Road TTC Class 9	02-Site	0.4
2nd Absolute Visc Default	07-AC-Binder-AC-1	0.1
2nd Kinematic Visc (325)	07-AC-Binder-AC-1	0.1
2nd AC PG Grade 76-22 Default	07-AC-Binder-SP-3	0.1
2nd AC Air Voids +2.5%	07-AC-General	0.2
2nd AC Air Voids −2%	07-AC-General	0.3
2nd AC Effective Binder Content +3%	07-AC-General	0.4
2nd AC Effective Binder Content −3%	07-AC-General	0.3
SG Default Soil Water Values	10-SG-ICM	0.4
SG High Soil Water Values	10-SG-ICM	0.4
SG Low Soil Water Values	10-SG-ICM	0.4

Table H-4. Wet-Warm, AC-Thick, Significant Variables - Alligator Cracking.

Description	Category	Allig-Rank
Minor Arterial TTC Class 4	02-Site	0.7
AADT −2318 (20%)	03-Traffic	0.9
AADT +2318 (20%)	03-Traffic	1.1
Wander 2" Less	03-Traffic-General	1.7
Wander 2" More	03-Traffic-General	1.8
Water Table Depth at 1'	04-Climate	0.6
AC 2nd AC Layer +1"	07-AC	0.8
AC 2nd AC Layer −1"	07-AC	0.7
AC Top Layer +1"	07-AC	0.8
AC Top Layer −1"	07-AC	0.7
Softening Point (170)	07-AC-Binder-AC-1	1.6
2nd AC Visc Grade 20 (Deflt)	07-AC-Binder-AC-3	0.9
2nd AC Visc Grade 30	07-AC-Binder-AC-3	1.4
2nd AC Visc Grade 40	07-AC-Binder-AC-3	2.1
2nd AC PG Grade 70-22	07-AC-Binder-SP-3	1.5
2nd AC PG Grade 82-22	07-AC-Binder-SP-3	1.8
AC Air Voids + 0.5%	07-AC-General	2.2
2nd AC % Pass #200 −3%	07-AC-Mix	1.8
2nd AC All Gradations on Low Side	07-AC-Mix	1.5
2nd AC Dynamic Modulus/1.5	07-AC-Mix	0.5
2nd AC Dynamic Modulus×1.5	07-AC-Mix	0.6
AC Dynamic Modulus×1.5	07-AC-Mix	1.2
AC Dynamic Modulus/1.5	07-AC-Mix	1.1
CHLS Default Soil Water Values	09-CHLS-ICM	2.1
CHLS P200 +70%	09-CHLS-ICM	2.4
CHLS P200 −10%	09-CHLS-ICM	1.0
CHLS PI −2	09-CHLS-ICM	0.6
CHLS Uncompacted	09-CHLS-ICM	2.3
CHLS Unit Wt −12 pcf	09-CHLS-ICM	2.3
CH Lime Stab Layer +2"	09-CHLS-Str	2.3
CH Lime Stab Layer −2"	09-CHLS-Str	1.9
CHLS Resilient Modulus×0.7	09-CHLS-Str	1.3
CHLS Resilient Modulus×1.3	09-CHLS-Str	1.4
SG Sat Hyd Cond/100	10-SG-ICM	1.5
SG Resilient Modulus +4 ksi	10-SG-Str	0.7
SG Resilient Modulus −2 ksi	10-SG-Str	0.9
SG Thickness −25"	10-SG-Str	1.2
BR Deleted	11-BR	0.6

Table H-5. Wet-Warm, AC-Thick, Highly Significant Variables - AC Rutting.

Description	Category	ACRut-Rank
All Tire Press +30 psi	03-Traffic-General-Axle	0.5
All Tire Press −30 psi	03-Traffic-General-Axle	0.3
Dual Tire Press +30 psi	03-Traffic-General-Axle	0.5
Dual Tire Press −30 psi	03-Traffic-General-Axle	0.3
2nd Absolute Visc Default	07-AC-Binder-AC-1	0.1
2nd Kinematic Visc (325)	07-AC-Binder-AC-1	0.1
Softening Point (170)	07-AC-Binder-AC-1	0.3
2nd AC PG Grade 76-22 Default	07-AC-Binder-SP-3	0.1
AC PG Grade 64-28	07-AC-Binder-SP-3	0.5
AC Air Voids +2.5%	07-AC-General	0.4
AC Dynamic Modulus×1.5	07-AC-Mix	0.3
AC Dynamic Modulus/1.5	07-AC-Mix	0.2
SG Thickness −25"	10-SG-Str	0.4
BR Deleted	11-BR	0.5

Table H-6. Wet-Warm, AC-Thick, Significant Variables - AC Rutting.

Description	Category	ACRut-Rank
Local Road TTC Class 9	02-Site	0.7
Minor Arterial TTC Class 4	02-Site	2.3
AADT −2318 (20%)	03-Traffic	0.9
AADT +2318 (20%)	03-Traffic	1.1
Wander 2" LESS	03-Traffic-General	1.7
Surface Shortwave Absorptivity −0.05	06-Drain	1.4
Surface Shortwave Absorptivity +0.05	06-Drain	1.4
AC Top Layer −1"	07-AC	2.1
AC Visc Grade 20 Softer	07-AC-Binder-AC-3	0.8
AC G* Delta×3	07-AC-Binder-SP-1	1.0
AC G* Delta/3	07-AC-Binder-SP-1	0.7
AC PG Grade 76-22	07-AC-Binder-SP-3	0.6
AC Air Voids −2%	07-AC-General	0.6
AC Effective Binder Content +2%	07-AC-General	1.1
AC Effective Binder Content −3%	07-AC-General	0.6
AC Heat Capacity +0.08	07-AC-General	1.7
AC Heat Capacity +0.17	07-AC-General	1.1
AC Poisson's Ratio −0.05	07-AC-General	0.7
AC Poisson's Ratio +0.05	07-AC-General	0.6
2nd AC Dynamic Modulus×1.5	07-AC-Mix	2.4
AC % Pass #200 +2%	07-AC-Mix	1.8
AC All Gradations on Hi Side	07-AC-Mix	1.7
AC Dynamic Modulus Default	07-AC-Mix	0.6
AC Top % Retained #4 +6%	07-AC-Mix	1.4
AC Top % Retained #4 −6%	07-AC-Mix	1.5
AC Top % Retained 3/8" +7.5%	07-AC-Mix	2.3
AC Top % Retained 3/8" −7.5%	07-AC-Mix	2.0
SG Default Soil Water Values	10-SG-ICM	1.8
SG High Soil Water Values	10-SG-ICM	2.3
SG Low Soil Water Values	10-SG-ICM	1.8

Table H-7. Wet-Warm, AC-Thick, Highly Significant Variables - Total Rutting Rank.

Description	Category	TotR-Rank
All Tire Press −30psi	03-Traffic-General-Axle	0.4
Dual Tire Press −30psi	03-Traffic-General-Axle	0.4
2nd Absolute Visc Default	07-AC-Binder-AC-1	0.1
2nd Kinematic Visc (325)	07-AC-Binder-AC-1	0.1
Softening Point (170)	07-AC-Binder-AC-1	0.3
2nd AC PG Grade 76-22 Default	07-AC-Binder-SP-3	0.1
AC Air Voids +2.5%	07-AC-General	0.4
AC Dynamic Modulus×1.5	07-AC-Mix	0.3
AC Dynamic Modulus/1.5	07-AC-Mix	0.2
BR Deleted	11-BR	0.3

Table H-8. Wet-Warm, AC-Thick, Highly Significant Variables - Total Rutting Rank.

Description	Category	TotR-Rank
Local Road TTC Class 9	02-Site	0.6
Minor Arterial TTC Class 4	02-Site	1.2
AADT −2318 (20%)	03-Traffic	0.9
AADT +2318 (20%)	03-Traffic	1.1
Wander 2" LESS	03-Traffic-General	2.0
ALL Tire Press +30 psi	03-Traffic-General-Axle	0.6
Dual Tire Press +30 psi	03-Traffic-General-Axle	0.6
Water Table Depth at 1'	04-Climate	0.6
Water Table Depth at 2'	04-Climate	0.8
Surface Shortwave Absorptivity −0.05	06-Drain	1.6
Surface Shortwave Absorptivity +0.05	06-Drain	1.6
AC Visc Grade 20 Softer	07-AC-Binder-AC-3	0.9
AC G* Delta×3	07-AC-Binder-SP-1	1.3
AC G* Delta/3	07-AC-Binder-SP-1	0.9
AC PG Grade 64-28	07-AC-Binder-SP-3	0.6
AC PG Grade 76-22	07-AC-Binder-SP-3	0.7
AC Air Voids −2%	07-AC-General	0.7
AC Effective Binder Content +2%	07-AC-General	1.3
AC Effective Binder Content −3%	07-AC-General	0.7
AC Heat Capacity +0.08	07-AC-General	2.1
AC Heat Capacity +0.17	07-AC-General	1.3
AC Poisson’s Ratio −0.05	07-AC-General	0.8
AC Poisson’s Ratio +0.05	07-AC-General	0.7
AC % Pass #200 +2%	07-AC-Mix	2.2
AC All Gradations on Hi Side	07-AC-Mix	2.0
AC Dynamic Modulus Default	07-AC-Mix	0.7
AC Top % Retained #4 +6%	07-AC-Mix	1.6
AC Top % Retained #4 −6%	07-AC-Mix	1.7
AC Top % Retained 3/8" −7.5%	07-AC-Mix	2.4
SG Default Soil Water Values	10-SG-ICM	1.7
SG High Soil Water Values	10-SG-ICM	1.5
SG Low Soil Water Values	10-SG-ICM	1.7
SG Resilient Modulus +4 ksi	10-SG-Str	1.7
SG Resilient Modulus −2 ksi	10-SG-Str	1.0
SG Thickness −25"	10-SG-Str	2.3

Table H-9. Wet-Warm, AC-Thick, Highly Significant Variables - IRI Rank.

Description	Category	IRI-Rank
Initial IRI +12	02-Analysis	0.2
Initial IRI −13	02-Analysis	0.2
Latitude −1.1	04-Climate	0.4
Longitude +0.7	04-Climate	0.4
2nd Absolute Visc Default	07-AC-Binder-AC-1	0.0
2nd Kinematic Visc (325)	07-AC-Binder-AC-1	0.0
2nd AC PG Grade 76-22 Default	07-AC-Binder-SP-3	0.0
2nd AC Air Voids +2.5%	07-AC-General	0.1
2nd AC Air Voids −2%	07-AC-General	0.4
2nd AC Effective Binder Content +3%	07-AC-General	0.5
2nd AC Effective Binder Content −3%	07-AC-General	0.2
2nd AC Dynamic Modulus/1.5	07-AC-Mix	0.4
SG Default Soil Water Values	10-SG-ICM	0.5
SG High Soil Water Values	10-SG-ICM	0.5
SG Low Soil Water Values	10-SG-ICM	0.5

Table H-10. Wet-Warm, AC-Thick, Significant Variables - IRI Rank.

Description	Category	IRI-Rank
Base Construction −2 months	01-General	2.2
Local Road TTC Class 9	02-Site	0.5
Minor Arterial TTC Class 4	02-Site	0.8
AADT −2318 (20%)	03-Traffic	1.0
AADT +2318 (20%)	03-Traffic	1.0
Wander 2" Less	03-Traffic-General	1.6
Wander 2" More	03-Traffic-General	1.9
Latitude +0.6	04-Climate	1.6
Longitude −0.8	04-Climate	1.4
Water Table Depth at 1'	04-Climate	0.6
AC 2nd AC Layer +1"	07-AC	0.9
AC 2nd AC Layer −1"	07-AC	0.6
AC Top Layer +1"	07-AC	0.9
AC Top Layer −1"	07-AC	0.6
Softening Point (170)	07-AC-Binder-AC-1	1.6
2nd AC Visc Grade 20 (Deflt)	07-AC-Binder-AC-3	0.8
2nd AC Visc Grade 30	07-AC-Binder-AC-3	1.3
2nd AC Visc Grade 40	07-AC-Binder-AC-3	1.9
2nd AC G* Delta (Default)	07-AC-Binder-SP-1	2.3
2nd AC PG Grade 70-22	07-AC-Binder-SP-3	1.4
2nd AC PG Grade 82-22	07-AC-Binder-SP-3	1.9
AC Air Voids +0.5%	07-AC-General	2.0
2nd AC % Pass #200 −3%	07-AC-Mix	1.6
2nd AC All Gradations on Low Side	07-AC-Mix	1.4
2nd AC Dynamic Modulus Default	07-AC-Mix	2.3
2nd AC Dynamic Modulus×1.5	07-AC-Mix	0.6
AC 2ndAC % Retained #4 +7.5%	07-AC-Mix	2.3
AC Dynamic Modulus×1.5	07-AC-Mix	1.4
AC Dynamic Modulus/1.5	07-AC-Mix	1.1
CHLS P200 +70%	09-CHLS-ICM	0.8
CHLS P200 −10%	09-CHLS-ICM	1.6
CHLS PI −2	09-CHLS-ICM	0.9
CH Lime Stab Layer −2"	09-CHLS-Str	2.3
CHLS Resilient Modulus×0.7	09-CHLS-Str	1.6
CHLS Resilient Modulus×1.3	09-CHLS-Str	2.0
SG Sat Hyd Cond/100	10-SG-ICM	1.4
SG Resilient Modulus +4 ksi	10-SG-Str	0.8
SG Resilient Modulus −2 ksi	10-SG-Str	0.8
SG Thickness −25"	10-SG-Str	1.1
BR Deleted	11-BR	0.5

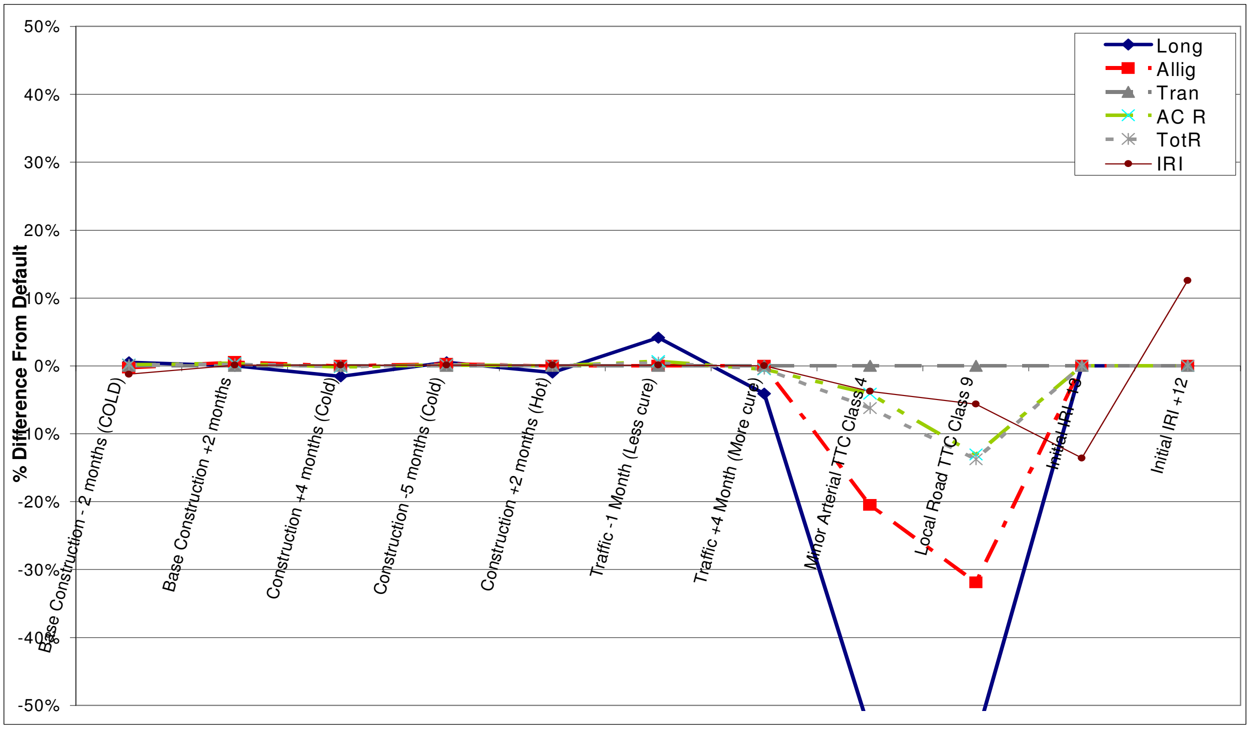

Figure H-1. Wet-Warm, AC-Thick, General Variables.

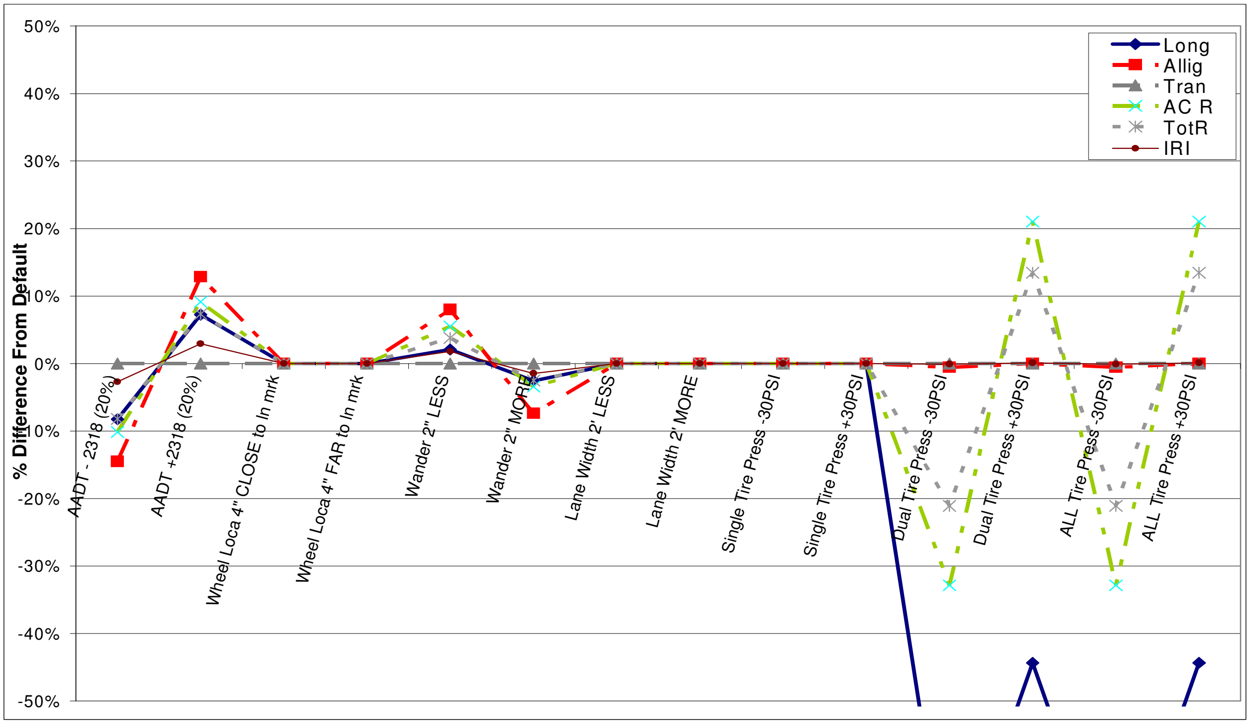

Figure H-2. Wet-Warm, AC-Thick, Traffic Variables.

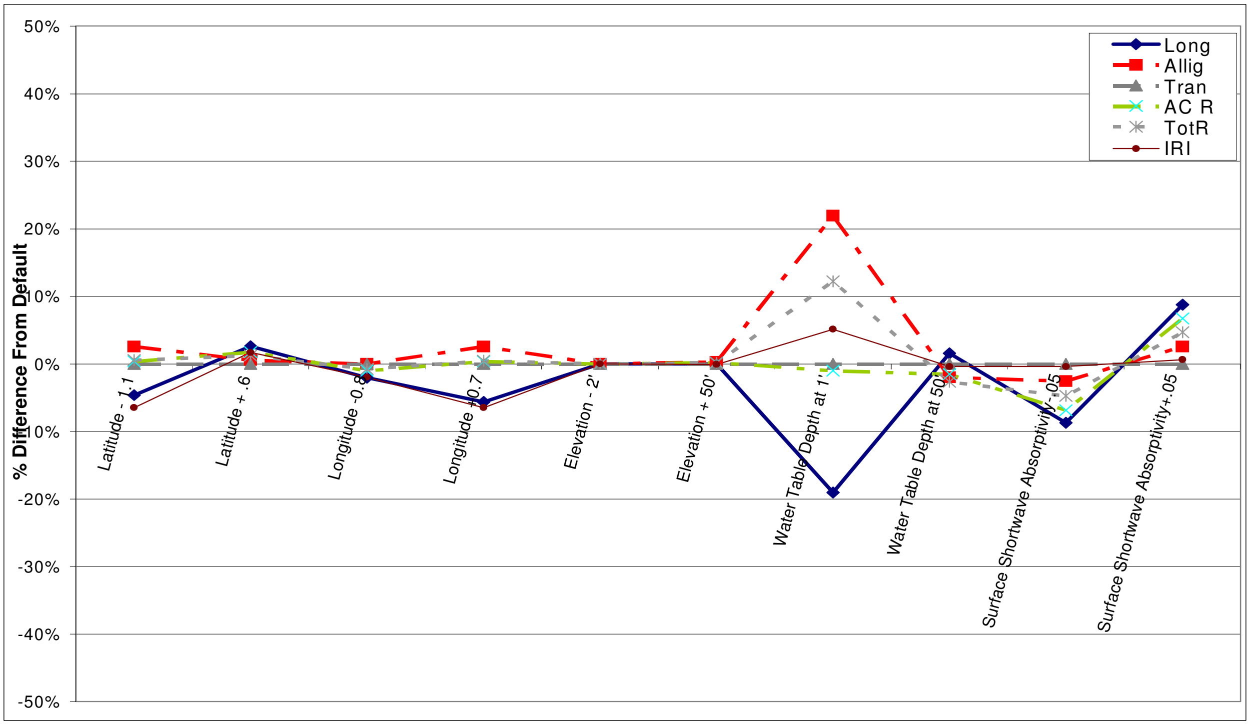

Figure H-3. Wet-Warm, AC-Thick, Climate Variables.

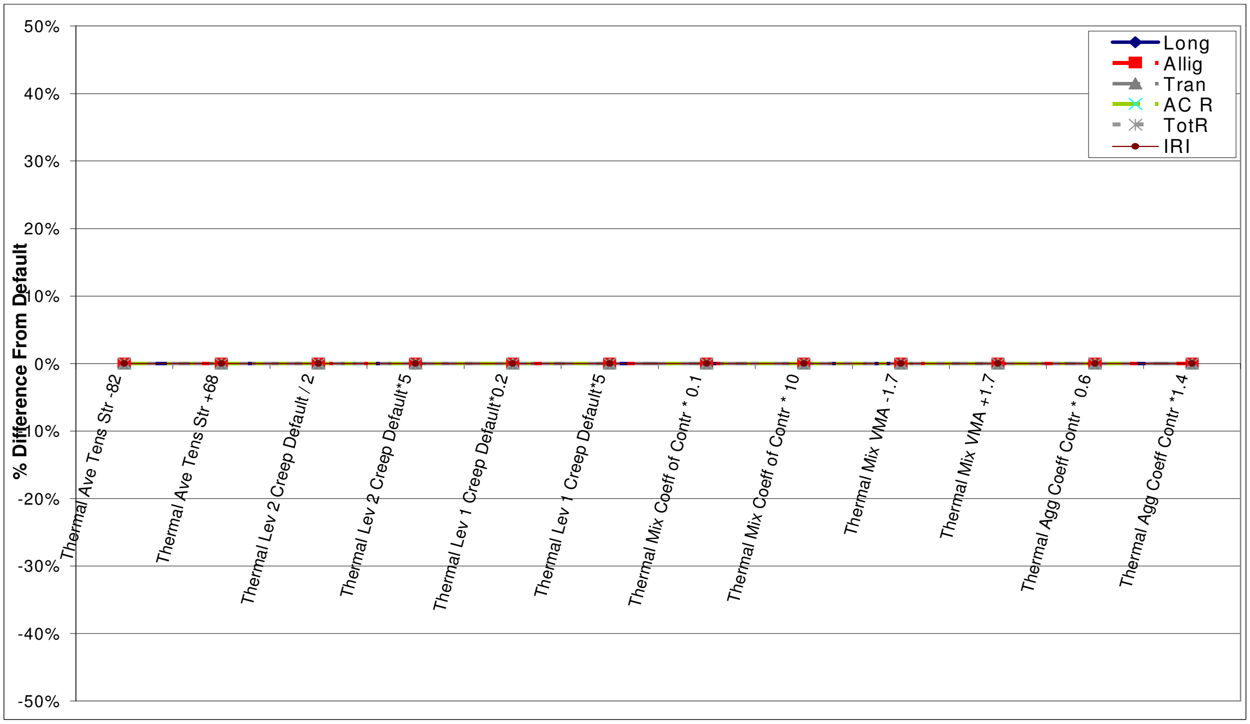

Figure H-4. Wet-Warm, AC-Thick, Thermal Variables.

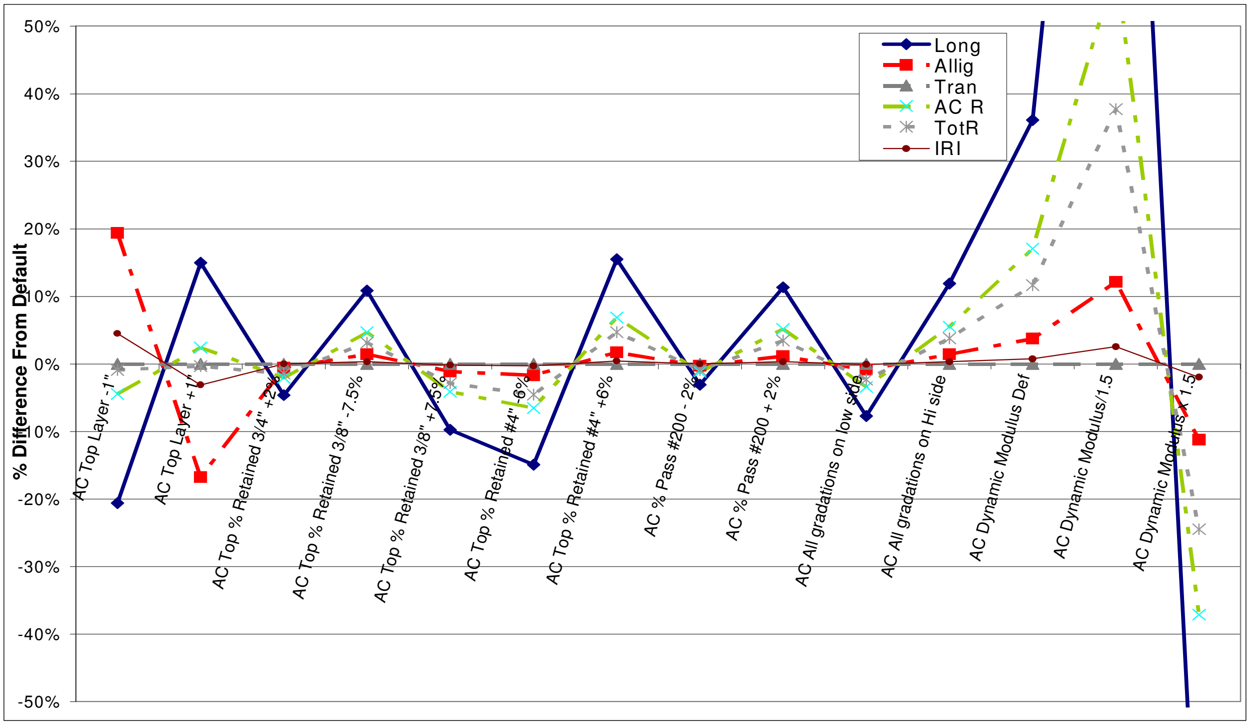

Figure H-5. Wet-Warm, AC-Thick, AC Top Mix Variables.

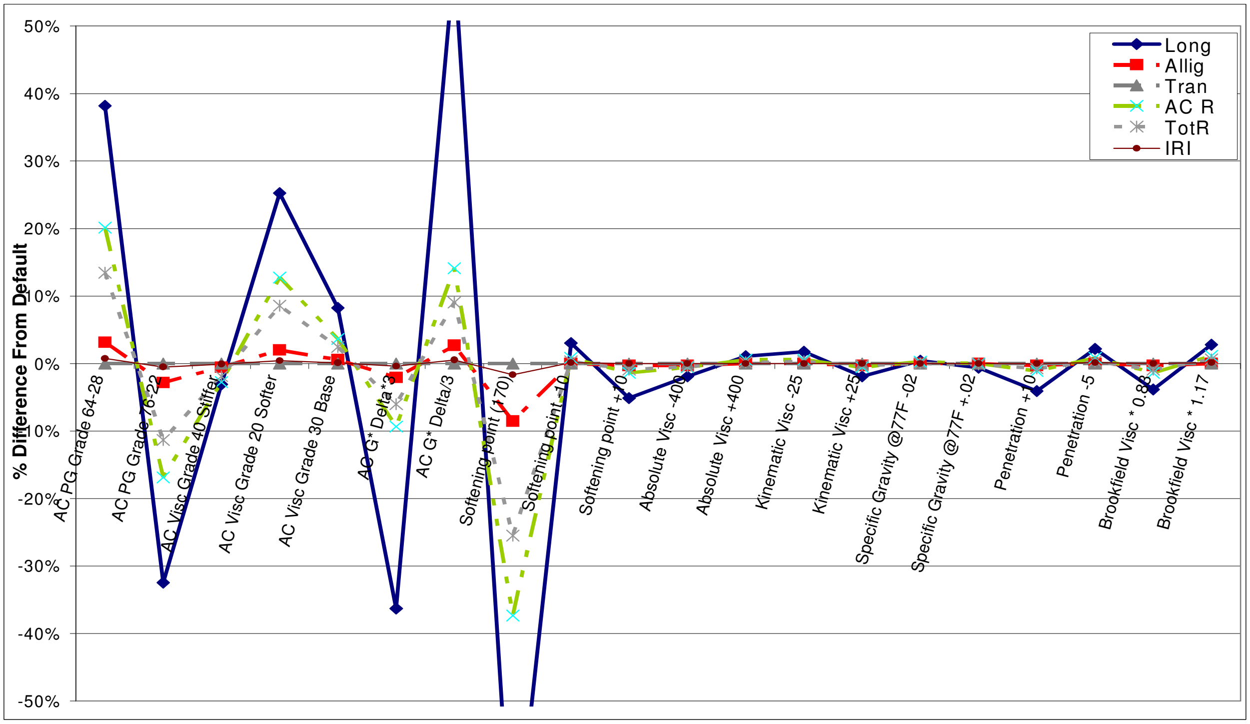

Figure H-6. Wet-Warm, AC-Thick, AC Top Layer Binder Variables.

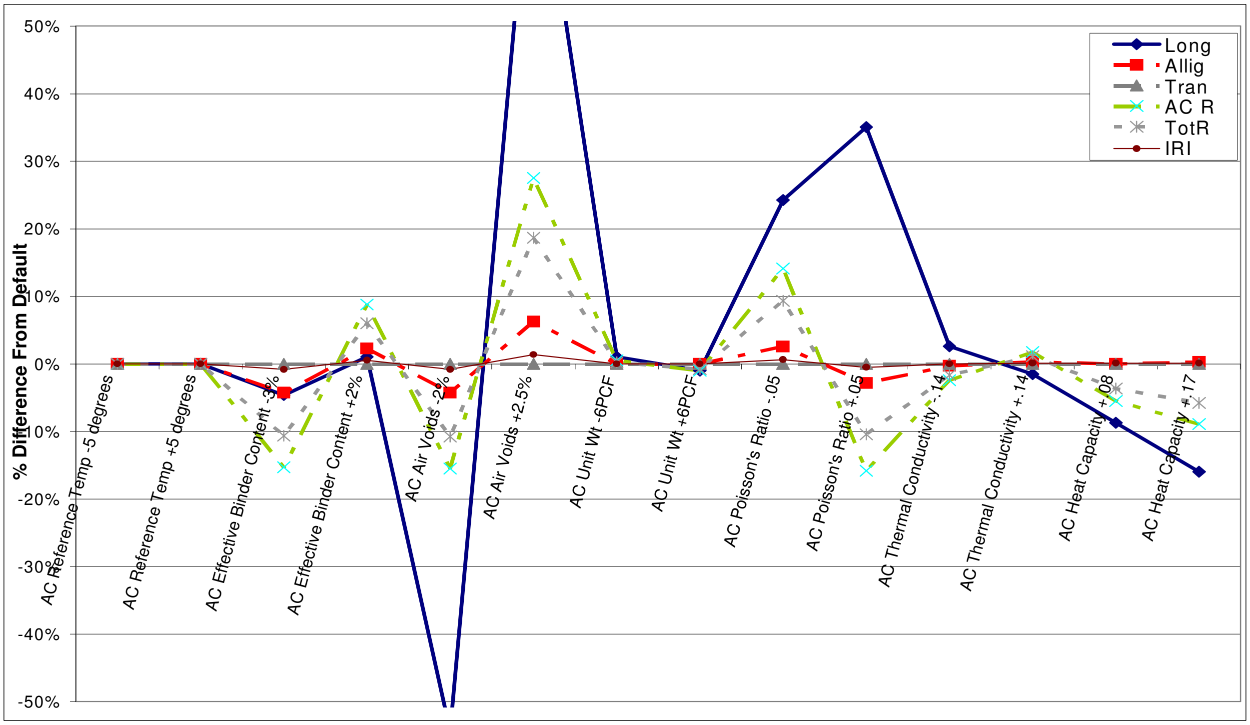

Figure H-7. Wet-Warm, AC-Thick, AC Top Layer General Variables.

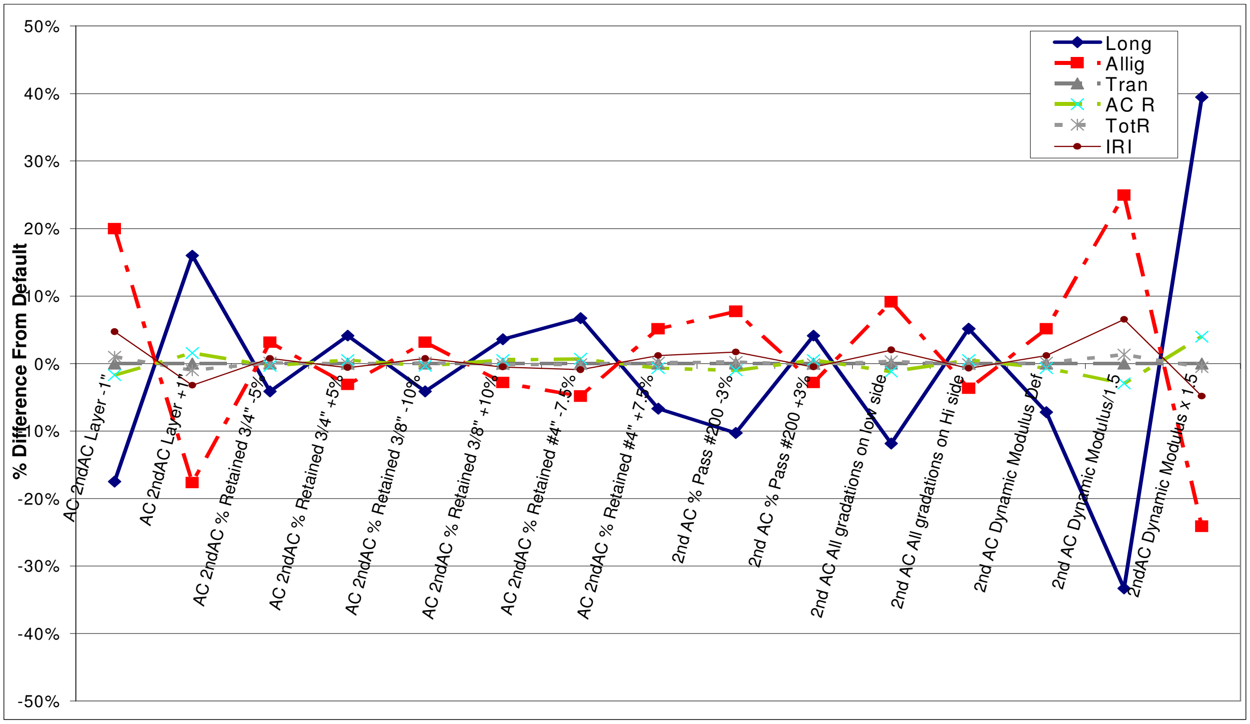

Figure H-8. Wet-Warm, AC-Thick, AC 2nd Layer Mix Variables.

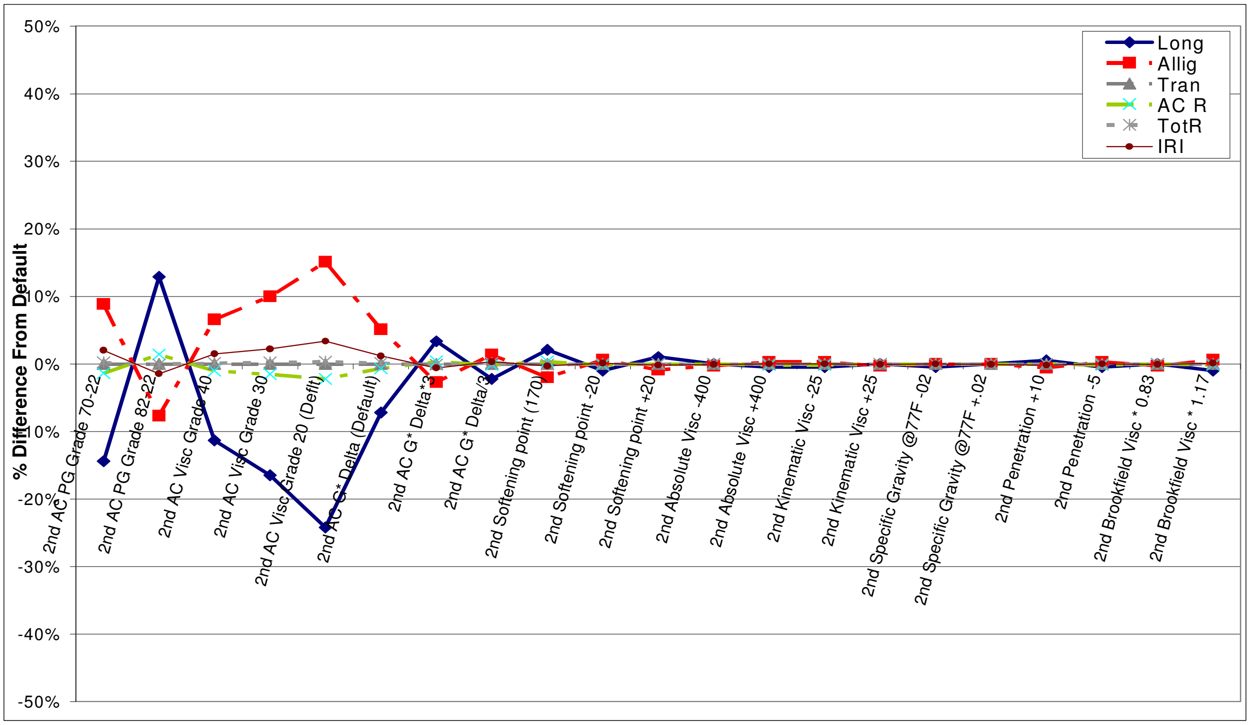

Figure H-9. Wet-Warm, AC-Thick, AC 2nd Layer Binder Variables.

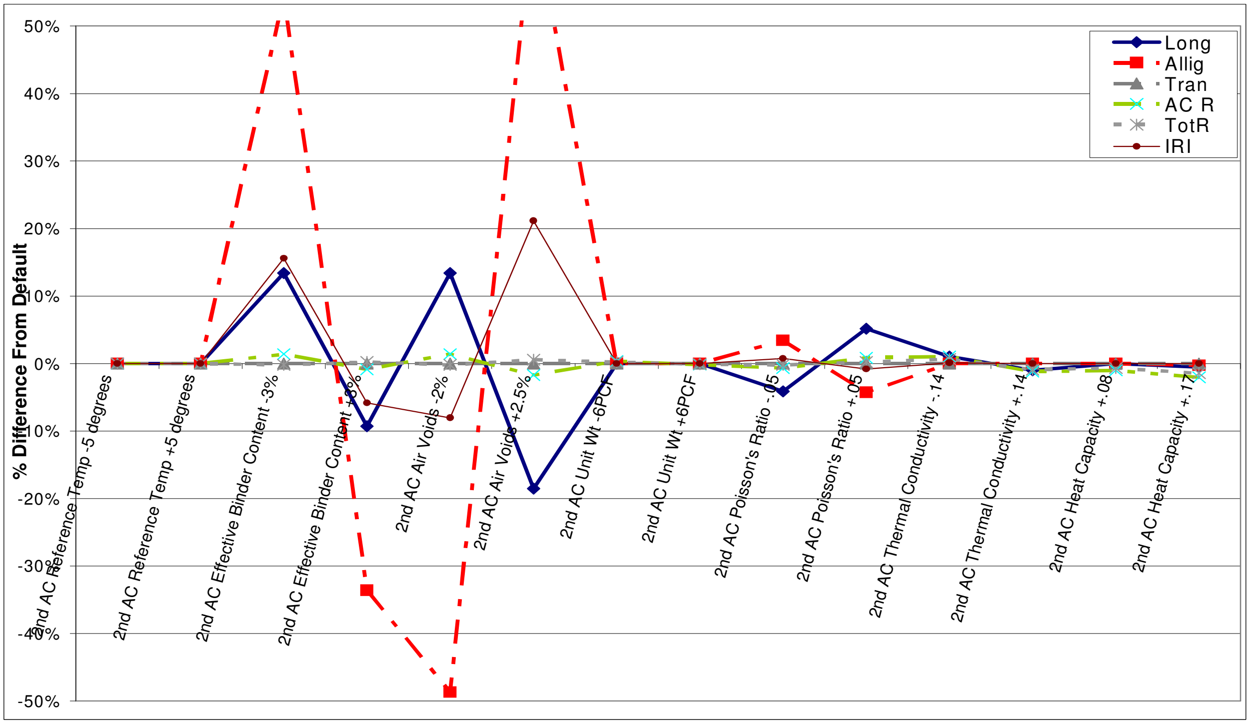

Figure H-10. Wet-Warm, AC-Thick, AC 2nd Layer General Variables.

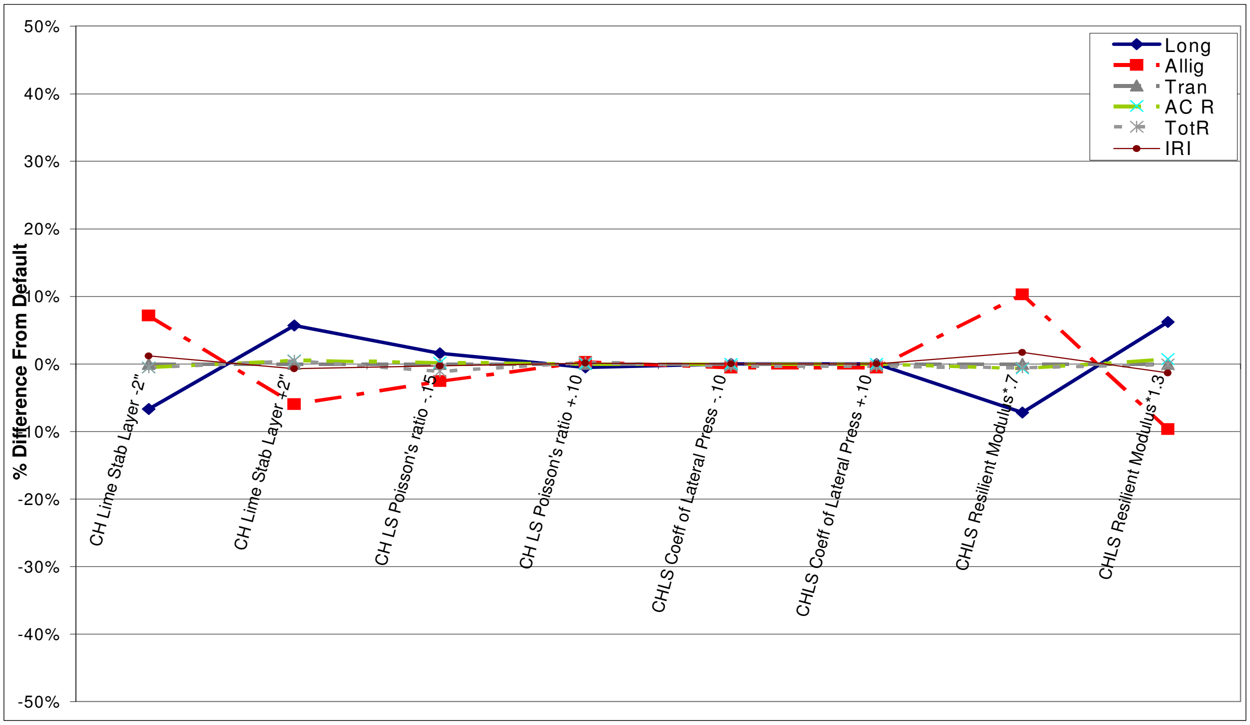

Figure H-11. Wet-Warm, AC-Thick, Lime-Modified Structural Variables.

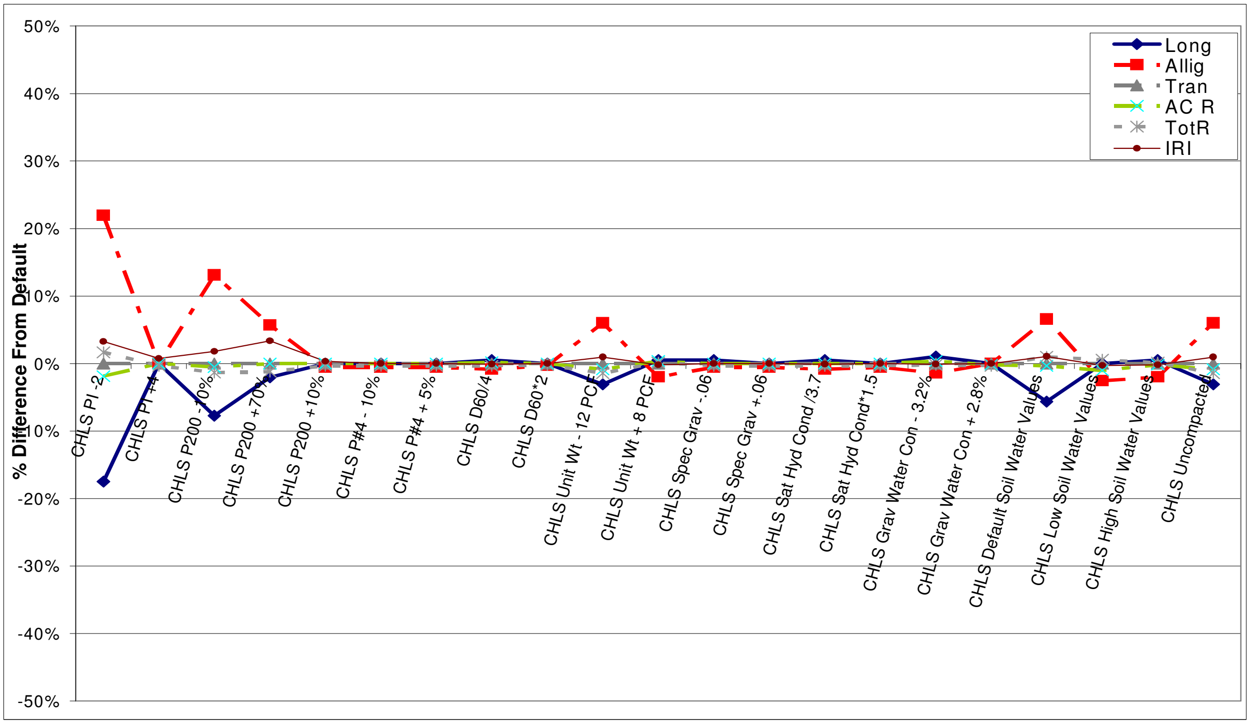

Figure H-12. Wet-Warm, AC-Thick, Lime-Modified Climatic Variables.

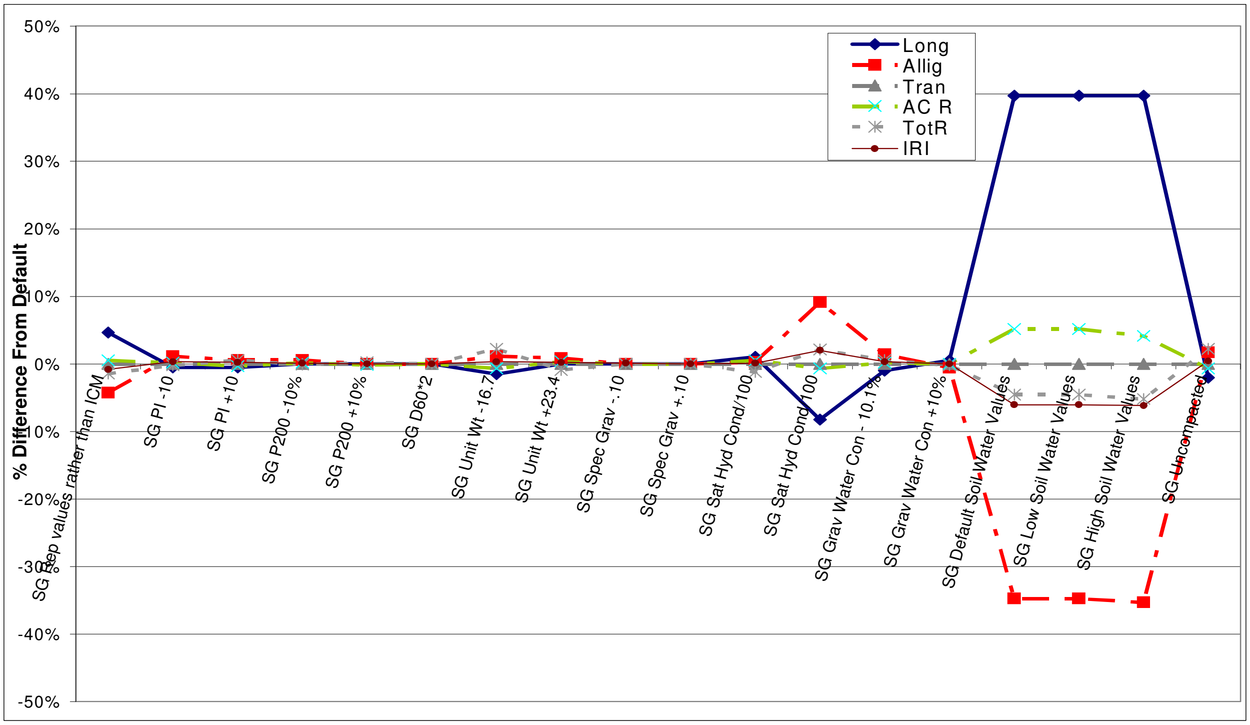

Figure H-13. Wet-Warm, AC-Thick, Subgrade Climatic Variables.

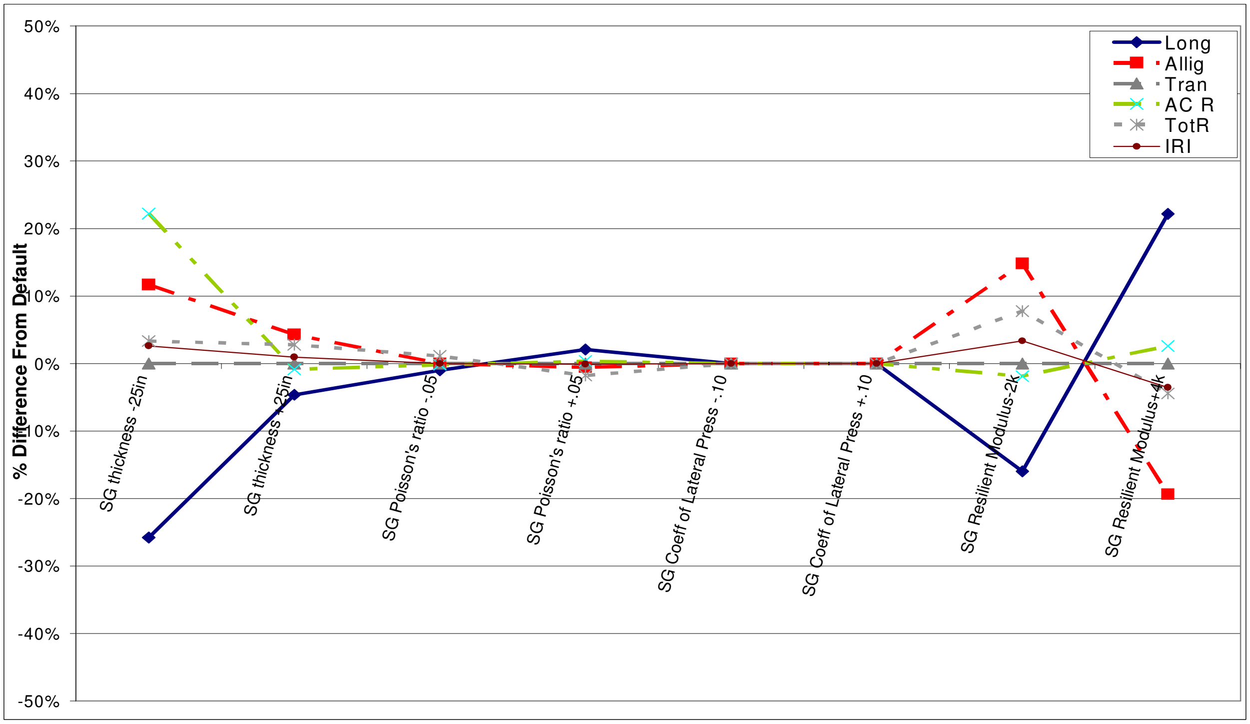

Figure H-14. Wet-Warm, AC-Thick, Subgrade Structural Variables.

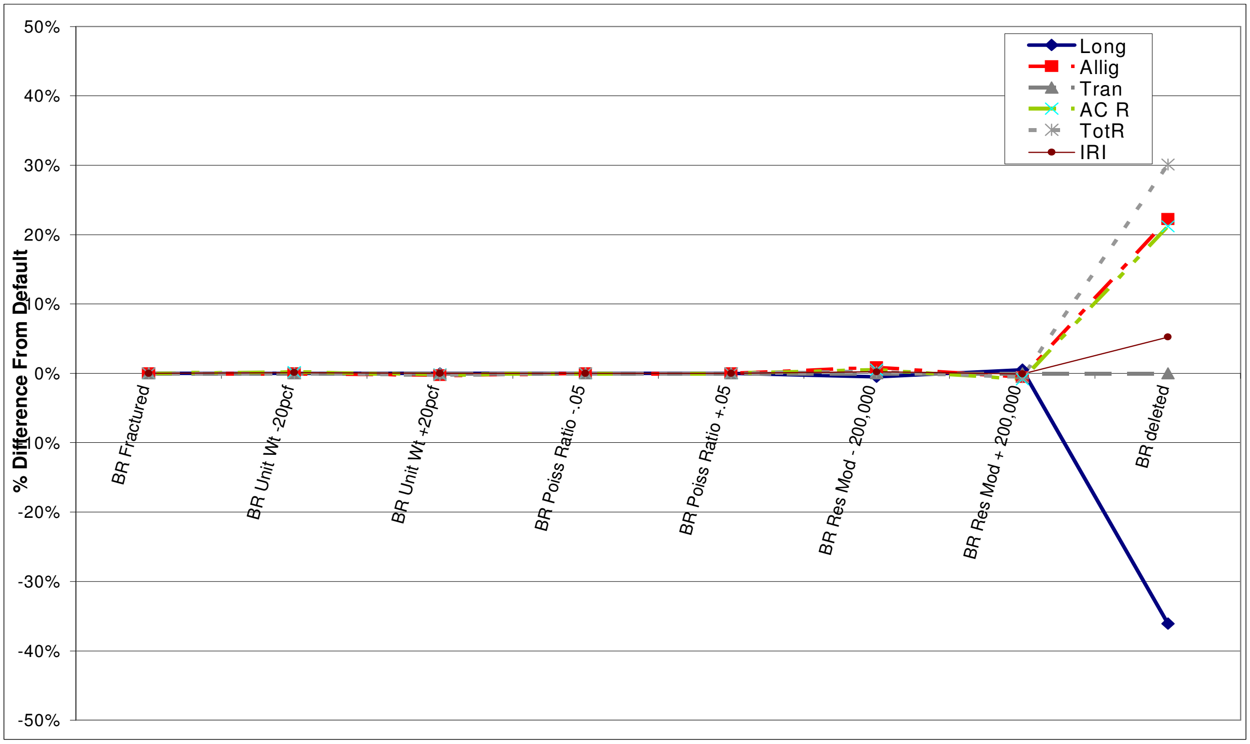

Figure H-15. Wet-Warm, AC-Thick, Bedrock Variables.

Table H-11. Results of Wet-Warm, AC-Thick, General Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
Base Construction −2 month	>	<	>	>	<<
Base Construction +2 month	=	>	>	>	>
Construction +2 month	<	=	=	=	>
Construction +4 month	<	=	<	<	>
Construction −5 month	>	>	>	>	>
Traffic +4 month	<<	=	<	<	=
Traffic −1 month	>>	=	>	>	>
Initial IRI +12	=	=	=	=	>>>
Initial IRI −13	=	=	=	=	<<<
Local Road TTC Class 9	<<<	<<<	<<	<<	<<
Minor Arterial TTC Class 4	<<<	<<	<<	<<	<<

Table H-12. Results of Wet-Warm, AC-Thick, Traffic Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
AADT −2318 (20%)	<<	<<	<<	<<	<<
AADT +2318 (20%)	>>	>>	>>	>>	>>
Lane Width 2' Less	=	=	=	=	=
Lane Width 2' More	=	=	=	=	=
Wander 2" Less	>	>>	>>	>>	>>
Wander 2" More	<	<<	<	<	<<
Wheel Location 4" Closer to Lane	=	=	=	=	=
Wheel Location 4" Far to Lane	=	=	=	=	=
All Tire Press +30 psi	<<<	=	>>>	>>	>
All Tire Press −30 psi	<<<	<	<<<	<<<	<
Dual Tire Press +30 psi	<<<	=	>>>	>>	>
Dual Tire Press −30 psi	<<<	<	<<<	<<<	<
Single Tire Press +30 psi	=	=	=	=	=
Single Tire Press −30 psi	=	=	=	=	=

Table H-13. Results of Wet-Warm, AC-Thick, Climate Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
Elevation −2'	=	=	=	=	=
Elevation +50'	=	>	>	>	<
Latitude −1.1	< <	>	>	>	< < <
Latitude +0.6	>	>	>	>	> >
Longitude +0.7	< <	>	>	>	< < <
Longitude −0.8	<	=	<	<	< <
Water Table Depth at 1'	< < <	> >	<	> >	> >
Water Table Depth at 2'	< < <	> >	<	> >	> >
Water Table Depth at 20' - Def	=	=	=	=	=
Water Table Depth at 50'	>	<	<	<	<
Surface Shortwave Absorptivity - 0.05	< <	<	< <	< <	<
Surface Shortwave Absorptivity +0.05	> >	>	> >	> >	>

Table H-14. Results of Wet-Warm, AC-Thick, AC Thermal Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
Thermal Agg Coeff Contr×0.6	=	=	=	=	=
Thermal Agg Coeff Contr×1.4	=	=	=	=	=
Thermal Ave Tens Str +68	=	=	=	=	=
Thermal Ave Tens Str −82	=	=	=	=	=
Thermal Lev 1 Creep Default	=	=	=	=	=
Thermal Lev 1 Creep Default×0.2	=	=	=	=	=
Thermal Lev 1 Creep Default×5	=	=	=	=	=
Thermal Lev 2 Creep Default	=	=	=	=	=
Thermal Lev 2 Creep Default/2	=	=	=	=	=
Thermal Lev 2 Creep Default×5	=	=	=	=	=
Thermal Mix Coeff of Contr×0.1	=	=	=	=	=
Thermal Mix Coeff of Contr×10	=	=	=	=	=
Thermal Mix VMA +1.7%	=	=	=	=	=
Thermal Mix VMA −1.7%	=	=	=	=	=

Table H-15. Results of Wet-Warm, AC-Thick, AC Binder Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
AC 2nd AC Layer +1"	>>>	<<	>	<	<<
AC 2nd AC Layer −1"	<<<	>>	<	>	>>
AC Top Layer +1"	>>>	<<	>	<	<<
AC Top Layer −1"	<<<	>>	<<	<	>>
2nd Absolute Visc +400	<	>	<	=	=
2nd Absolute Visc −400	=	<	=	=	<
2nd Absolute Visc Default	<<<	<<<	<<<	<<<	<<<
2nd Brookfield Visc×0.83	=	<	=	=	<
2nd Brookfield Visc×1.17	<	>	<	=	>
2nd Kinematic Visc (325)	<<<	<<<	<<<	<<<	<<<
2nd Kinematic Visc +25	=	<	=	=	<
2nd Kinematic Visc −25	<	>	<	=	=
2nd Penetration +10	>	<	=	=	<
2nd Penetration −5	<	>	<	=	=
2nd Softening Point (170)	>	<	>	<	<
2nd Softening Point +20	>	<	=	=	<
2nd Softening Point −20	<	>	<	=	>
2nd Specific Gravity @77°F +0.02	=	=	=	=	<
2nd Specific Gravity @77°F −0.02	<	=	=	=	=
Absolute Visc +400	>	=	>	>	=
Absolute Visc −400	<	<	<	<	=
Brookfield Visc×0.83	<<	<	<	<	=
Brookfield Visc×1.17	>	=	>	>	>
Kinematic Visc +25	<	<	<	<	=
Kinematic Visc −25	>	=	>	>	=
Penetration +10	<<	<	<	<	=
Penetration −5	>	=	>	>	>
Softening Point (170)	<<<	<<	<<<	<<<	<<
Softening Point +10	<<	<	<	<	=
Softening Point −10	>>	=	>	>	>
Specific Gravity @77F +0.02	<	=	=	<	=
Specific Gravity @77F −0.02	>	=	>	=	=
2nd AC Visc Grade 20 Def	<<<	>>	<	>	>>
2nd AC Visc Grade 30	<<<	>>	<	>	>>
2nd AC Visc Grade 40	<<	>>	<	>	>>
AC Visc Grade 20 Softer	>>>	>	>>	>>	>

Table H-15. Results of Wet-Warm, AC-Thick, AC Binder Variables (Continued).

AC Visc Grade 30 Base	> >	>	>	>	>
AC Visc Grade 40 Stiffer	< <	<	<	<	<
2nd AC G* Delta (Default)	< <	>	<	>	> >
2nd AC G* Delta×3	> >	<	>	<	<
2nd AC G* Delta/3	<	>	<	>	>
AC G* Delta×3	< < <	<	< <	< <	<
AC G* Delta/3	> > >	>	> >	> >	>
2nd AC PG Grade 70-22	< < <	> >	<	>	> >
2nd AC PG Grade 76-22 Def	< < <	< < <	< < <	< < <	< < <
2nd AC PG Grade 82-22	> >	< <	>	<	< <
AC PG Grade 64-28	> > >	>	> > >	> >	>
AC PG Grade 76-22	< < <	<	< <	< <	<

Table H-16. Results of Wet-Warm, AC-Thick, General AC Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
2nd AC Air Voids +2.5%	< < <	> > >	<	>	> > >
2nd AC Air Voids −2%	> >	< < <	>	<	< < <
2nd AC Effective Binder Content +3%	< <	< < <	<	>	< <
2nd AC Effective Binder Content −3%	> >	> > >	>	<	> > >
2nd AC Heat Capacity +0.08	=	=	<	<	=
2nd AC Heat Capacity +0.17	<	<	<	<	=
2nd AC Poisson’s Ratio −0.05	< <	>	<	<	>
2nd AC Poisson’s Ratio +0.05	> >	<	>	>	<
2nd AC Reference Temp +5 °F	=	=	=	=	=
2nd AC Reference Temp −5 °F	=	=	=	=	=
2nd AC Thermal Conductivity −0.14	>	=	>	>	>
2nd AC Thermal Conductivity +0.14	<	=	<	<	=
2nd AC Unit Wt +6 pcf	=	=	<	<	=
2nd AC Unit Wt −6 pcf	=	=	>	>	=
AC Air Voids +2.5%	> > >	> >	> > >	> > >	> >
AC Air Voids −2%	< < <	<	< <	< <	<
AC Effective Binder Content +2%	>	>	> >	> >	>
AC Effective Binder Content −3%	< <	<	< <	< <	<
AC Heat Capacity +0.08	< <	=	< <	< <	>
AC Heat Capacity +0.17	< < <	>	< <	< <	>
AC Poisson’s Ratio −0.05	> > >	>	> >	> >	>
AC Poisson’s Ratio +0.05	> > >	<	< <	< <	<
AC Reference Temp +5 °F	=	=	=	=	=
AC Reference Temp −5 °F	=	=	=	=	=
AC Thermal Conductivity −0.14	>	<	<	<	=
AC Thermal Conductivity +0.14	<	>	>	>	>
AC Unit Wt +6 pcf	<	=	<	<	=
AC Unit Wt −6 pcf	>	=	>	>	=

Table H-17. Results of Wet-Warm, AC-Thick, AC Mix Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
2nd AC % Pass #200 +3%	>>	<	>	<	<
2nd AC % Pass #200 −3%	<<	>>	<	>	>>
2nd AC All Gradations on Hi Side	>>	<	>	<	<
2nd AC All Gradations on Low Side	<<	>>	<	>	>>
2nd AC Dynamic Modulus Def	<<	>	<	>	>>
2nd AC Dynamic Modulus/1.5	<<<	>>>	<	>	>>>
2nd AC Dynamic Modulus×1.5	>>>	<<	>>	<	<<
AC % Pass #200 −2%	<<	<	<	<	=
AC % Pass #200 +2%	>>	>	>>	>>	>
AC 2nd AC % Retained #4 +7.5%	<<	>	<	>	>>
AC 2nd AC % Retained #4 −7.5%	>>	<	>	<	<
AC 2nd AC % Retained 3/4" +5%	>>	<	>	<	<
AC 2nd AC % Retained 3/4" −5%	<<	>	<	>	>
AC 2nd AC % Retained 3/8" +10%	>>	<	>	<	<
AC 2nd AC % Retained 3/8" −10%	<<	>	<	>	>
AC All Gradations on Hi Side	>>	>	>>	>>	>
AC All Gradations on Low Side	<<	<	<	<	<
AC Dynamic Modulus Def	>>>	>	>>	>>	>
AC Dynamic Modulus×1.5	<<<	<<	<<<	<<<	<<
AC Dynamic Modulus/1.5	>>>	>>	>>>	>>>	>>
AC Top % Retained #4 +6%	>>>	>	>>	>>	>
AC Top % Retained #4 −6%	<<<	<	<<	<<	<
AC Top % Retained 3/4" +2%	<<	<	<	<	=
AC Top % Retained 3/8" +7.5%	<<	<	<<	<	<
AC Top % Retained 3/8" −7.5%	>>	>	>>	>>	>

Table H-18. Results of Wet-Warm, AC-Thick, Lime Treated ICM Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
CHLS D60×2	=	<	=	<	=
CHLS D60/4	>	<	>	<	<
CHLS Def Soil Water Values	<<	>>	<	>	>>
CHLS Grav Water Con −3.2%	>	<	>	<	<
CHLS Grav Water Con - Default	=	<	=	<	=
CHLS Grav Water Con +2.8%	=	=	<	<	=
CHLS High Soil Water Values	>	<	<	>	<
CHLS Low Soil Water Values	=	<	<	>	<
CHLS P#4 −10%	=	<	=	<	=
CHLS P#4 +5%	=	<	=	<	=
CHLS P200 +10%	=	<	=	<	>
CHLS P200 +70%	<	>>	=	<	>>
CHLS P200 −10%	<<	>>	<	<	>>
CHLS PI +4	=	=	=	<	>
CHLS PI −2	<<<	>>	<	>	>>
CHLS Sat Hyd Cond - Default	=	<	=	<	=
CHLS Sat Hyd Cond/3.7	>	<	=	<	<
CHLS Sat Hyd Cond×1.5	=	<	=	<	=
CHLS Soil Water Program Def	=	<	=	<	=
CHLS Spec Grav - Default	=	<	=	<	=
CHLS Spec Grav −0.06	>	<	=	<	=
CHLS Spec Grav +0.06	=	<	=	<	=
CHLS Uncompacted	<<	>>	<	<	>
CHLS Unit Wt −12 pcf	<<	>>	<	<	>
CHLS Unit Wt - Default	=	<	=	<	=
CHLS Unit Wt +8 pcf	>	<	>	>	<

Table H-19. Results of Wet-Warm, AC-Thick, Lime Treated Strength Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
CH Lime Stab Layer +2"	> >	< <	>	>	<
CH Lime Stab Layer −2"	< <	> >	<	<	> >
CH LS Poisson's Ratio −0.15	>	<	>	<	<
CH LS Poisson's Ratio +0.10	<	>	=	>	>
CHLS Coeff of Lateral Press −0.10	=	<	=	<	=
CHLS Coeff of Lateral Press +0.10	=	<	=	<	=
CHLS Resilient Modulus×0.7	< <	> >	<	<	> >
CHLS Resilient Modulus×1.3	> >	< <	>	<	< <

Table H-20. Results of Wet-Warm, AC-Thick, Subgrade ICM Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
SG D60×2	=	=	=	=	=
SG Default Soil Water Values	> > >	< < <	> >	< <	< <
SG Grav Water Con −10.1%	<	>	>	>	>
SG Grav Water Con - Default	=	=	=	=	=
SG Grav Water Con +10%	>	<	=	<	=
SG High Soil Water Values	> > >	< < <	> >	< <	< <
SG Low Soil Water Values	> > >	< < <	> >	< <	< <
SG P200 +10%	=	=	<	>	=
SG P200 −10%	=	>	>	<	>
SG PI +10	<	>	<	>	>
SG PI −10	<	>	>	<	>
SG Program Def Soil Water Values	=	=	=	=	=
SG Rep values rather than ICM	> >	<	>	<	<
SG Sat Hyd Cond Default	=	=	=	=	=
SG Sat Hyd Cond/100	>	>	>	<	>
SG Sat Hyd Cond/100	< <	> >	<	>	> >
SG Spec Grav - Default	=	=	=	=	=
SG Spec Grav −0.10	=	=	=	=	>
SG Spec Grav +0.10	=	=	=	=	=
SG Uncompacted	<	>	<	>	>
SG Unit Wt +23.4 pcf	=	>	>	<	>
SG Unit Wt −16.7 pcf	<	>	<	>	>
SG Unit Wt - Default	=	=	=	=	=

Table H-21. Results of Wet-Warm, AC-Thick, Subgrade Strength Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
SG Coeff of Lateral Press −0.10	=	=	=	=	=
SG Coeff of Lateral Press + 0.10	=	=	=	=	=
SG Poisson's Ratio −0.05	<	=	<	>	=
SG Poisson's Ratio +0.05	>	<	>	<	<
SG Resilient Modulus +4k	> > >	< <	>	< <	< <
SG Resilient Modulus −2k	< < <	> >	<	> >	> >
SG Thickness +25"	< <	>	<	>	>
SG Thickness - 25"	< < <	> >	> > >	> >	> >

Table H-22. Results of Wet-Warm, AC-Thick, Bedrock Variables.

Description	Long Rank	Allig Rank	AC Rut Rank	TotRut Rank	IRI Rank
BR Deleted	< < <	> >	> > >	> > >	> > >
BR Fractured	=	=	=	=	=
BR Poiss Ratio −0.05	=	=	=	=	=
BR Poiss Ratio +0.05	=	=	=	=	=
BR Res Mod −200,000	<	>	>	>	>
BR Res Mod +200,000	>	<	<	<	<
BR Unit Wt +20 pcf	=	<	<	<	=
BR Unit Wt −20 pcf	=	=	>	=	>

APPENDIX I

DRY-COLD, CRCP RESULTS

Table I-1. Dry-Cold, CRCP, Highly Significant Variables - Damage.

Description	Category	Damage
Construction −5 month (Cold)	01-General	0.4
Wheel Loca 4" Close Lane Mark	03-Traffic-General	0.4
Mean Crack Spacing −18"	06-Design	0.4
Steel % −0.2%	06-Design	0.4
Steel % +0.2%	06-Design	0.4
E +1000 ksi	08-CRC-Strength	0.3
Level 2 Min Compress Strength	08-CRC-Strength	0.4
Coefficient of Contraction +3	08-CRC-Thermal	0.2
CRC Thickness −2"	08-CRC-Thermal	0.2

Table I-2. Dry-Cold, CRCP, Significant Variables - Damage.

Description	Category	Damage
Construction +4 month	01-General	0.6
AADT −1600 (20%)	03-Traffic	1.0
AADT +1600 (20%)	03-Traffic	1.0
Wander 2" Less	03-Traffic-General	2.3
Wheel Loca 4" Far Lane Mark	03-Traffic-General	0.5
AC Shoulder	06-Design	0.7
Bar Diameter −0.125"	06-Design	0.6
Bar Diameter +0.125"	06-Design	1.3
Base/Slab Friction Coeff −3.4	06-Design	0.6
Base/Slab Friction Coeff +2.9	06-Design	0.6
Curl/Warp Temp Diff +4 °F	06-Design	1.0
Curl/Warp Temp Diff −5 °F	06-Design	0.6
Mean Crack Spacing +24"	06-Design	1.1
Steel at 1/4 Depth	06-Design	0.8
Zero Stress Temp +23 °F	08-CRC-Mix	0.9
Zero Stress Temp −27 °F	08-CRC-Mix	0.7
20Yr/28Day Ratio −0.15	08-CRC-Strength	2.5
E −800 ksi	08-CRC-Strength	1.6
Level 1 CRC Strength Data-High	08-CRC-Strength	0.5
Level 1 CRC Strength Data-Mid	08-CRC-Strength	0.8
Level 2 High Compress Strength	08-CRC-Strength	0.8
Level 3 Mr −40 psi	08-CRC-Strength	0.8
Level 3 Mr +50 psi	08-CRC-Strength	1.0
Ultimate Shrink +157 psi	08-CRC-Thermal	1.0
Ultimate Shrink −143 psi	08-CRC-Thermal	0.6
Unit Wt −5 pcf	08-CRC-Thermal	2.1
Coefficient of Contraction −2	08-CRC-Thermal	0.6
CRC Thickness +2"	08-CRC-Thermal	0.5

Table I-3. Dry-Cold, CRCP, Highly Significant Variables - Punchouts.

Description	Category	30Yr PO
Construction −5 month (Cold)	01-General	0.2
Construction +4 month	01-General	0.4
Wheel Loca 4" Far Lane Mark	03-Traffic-General	0.3
Bar Diameter −0.125"	06-Design	0.3
Base/Slab Friction Coeff +2.9	06-Design	0.3
Mean Crack Spacing −18"	06-Design	0.2
Steel % +0.2%	06-Design	0.2
Level 1 CRC Strength Data-High	08-CRC-Strength	0.2
Coefficient of Contraction +3	08-CRC-Thermal	0.3
Coefficient of Contraction −2	08-CRC-Thermal	0.3
CRC Thickness +2"	08-CRC-Thermal	0.2
CRC Thickness −2"	08-CRC-Thermal	0.3
Ultimate Shrink −143 psi	08-CRC-Thermal	0.4

Table I-4. Dry-Cold, CRCP, Significant Variables - Punchouts.

Description	Category	30Yr PO
AADT −1600	03-Traffic	0.8
AADT +600	03-Traffic	1.2
Wander 2" Less	03-Traffic-General	2.1
Wheel Loca 4" Close Lane Mark	03-Traffic-General	0.5
AC Shoulder	06-Design	0.9
Bar Diameter +0.125"	06-Design	1.5
Base/Slab Friction Coeff −3.4	06-Design	0.8
Curl/Warp Temp Diff +4 °F	06-Design	0.8
Curl/Warp Temp Diff −5 °F	06-Design	0.8
Mean Crack Spacing +24"	06-Design	1.3
Steel % −0.2%	06-Design	0.5
Steel at 1/4 Depth	06-Design	0.6
Zero Stress Temp +23 °F	08-CRC-Mix	1.1
Zero Stress Temp −27 °F	08-CRC-Mix	0.5
E +1000 ksi	08-CRC-Strength	0.5
E −800 ksi	08-CRC-Strength	1.8
Level 1 CRC Strength Data-Mid	08-CRC-Strength	0.6
Level 2 High Compress Strength	08-CRC-Strength	0.5
Level 2 Min Compress Strength	08-CRC-Strength	0.6
Level 3 Mr −40 psi	08-CRC-Strength	1.0
Level 3 Mr +50 psi	08-CRC-Strength	0.8
Ultimate Shrink +57 psi	08-CRC-Thermal	1.2
Unit Wt +5 pcf	08-CRC-Thermal	2.4
Unit Wt −5 pcf	08-CRC-Thermal	2.3

Table I-5. Dry-Cold, CRCP, Highly Significant Variables - IRI.

Description	Category	IRI
Construction −5 month (Cold)	01-General	0.2
Construction +4 month	01-General	0.4
Wheel Loca 4" Far Lane Mark	03-Traffic-General	0.3
Bar Diameter −0.125"	06-Design	0.3
Base/Slab Friction Coeff +2.9	06-Design	0.3
Mean Crack Spacing −18"	06-Design	0.2
Steel % +0.2%	06-Design	0.2
Level 1 CRC Strength Data-High	08-CRC-Strength	0.2
Coefficient of Contraction +3	08-CRC-Thermal	0.3
Coefficient of Contraction −2	08-CRC-Thermal	0.3
CRC Thickness +2"	08-CRC-Thermal	0.2
CRC Thickness −2"	08-CRC-Thermal	0.3
Ultimate Shrink −143 psi	08-CRC-Thermal	0.4

Table I-6. Dry-Cold, CRCP, Significant Variables - IRI.

Description	Category	IRI
AADT −1600 (20%)	03-Traffic	0.8
AADT +1600 (20%)	03-Traffic	1.2
Wander 2" Less	03-Traffic-General	2.1
Wheel Loca 4" Close Lane Mark	03-Traffic-General	0.5
Elevation −1500'	04-Climate	1.4
AC Shoulder	06-Design	0.9
Bar Diameter +0.125"	06-Design	1.4
Base/Slab Friction Coeff −3.4	06-Design	0.8
Curl/Warp Temp Diff +4	06-Design	0.8
Curl/Warp Temp Diff −5	06-Design	0.8
Mean Crack Spacing +24"	06-Design	1.2
Steel % −0.2%	06-Design	0.5
Steel at 1/4 Depth	06-Design	0.6
Zero Stress Temp +23 Degrees	08-CRC-Mix	1.0
Zero Stress Temp −27 Degrees	08-CRC-Mix	0.5
E +1000 ksi	08-CRC-Strength	0.5
E −800 ksi	08-CRC-Strength	1.7
Level 1 CRC Strength Data-Mid	08-CRC-Strength	0.6
Level 2 High Compress Strength	08-CRC-Strength	0.5
Level 2 Min Compress Strength	08-CRC-Strength	0.6
Level 3 Mr −40 psi	08-CRC-Strength	1.0
Level 3 Mr +50 psi	08-CRC-Strength	0.8
Ultimate Shrink +157 psi	08-CRC-Thermal	1.1
Unit Wt +5 pcf	08-CRC-Thermal	2.3
Unit Wt −5 pcf	08-CRC-Thermal	2.2

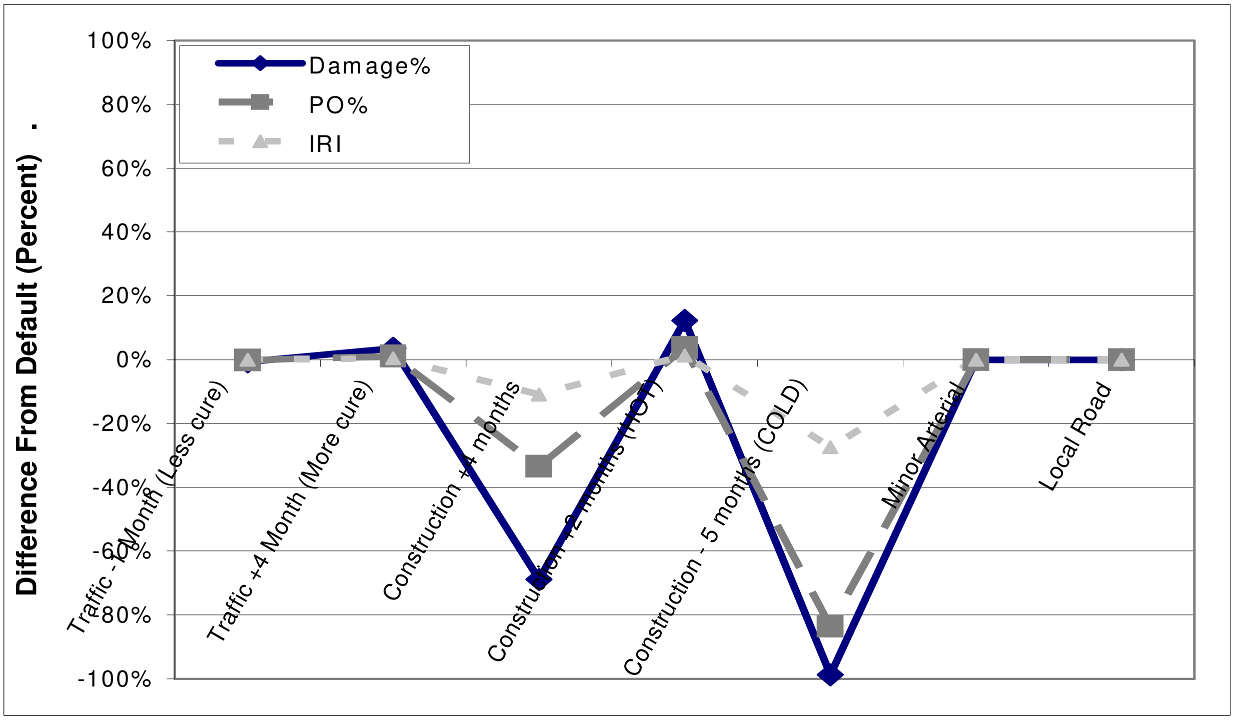

Figure I-1. Dry-Cold, CRCP, General Variables.

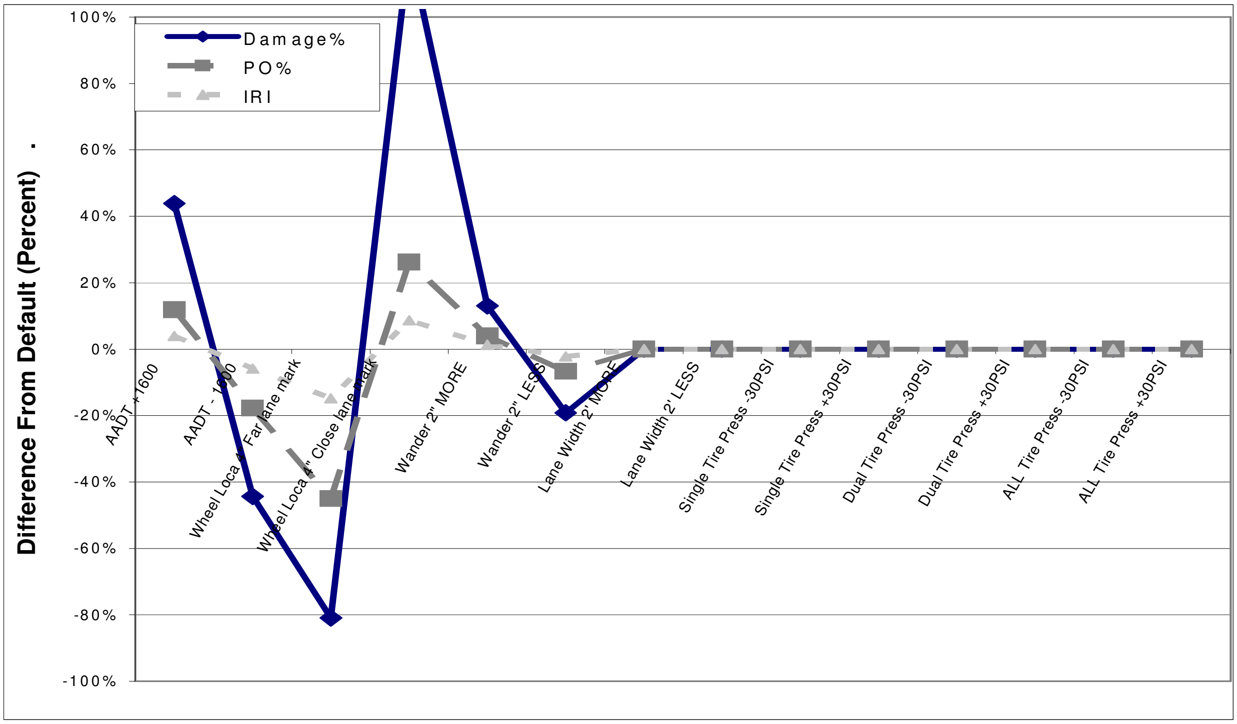

Figure I-2. Dry-Cold, CRCP, Traffic Variables.

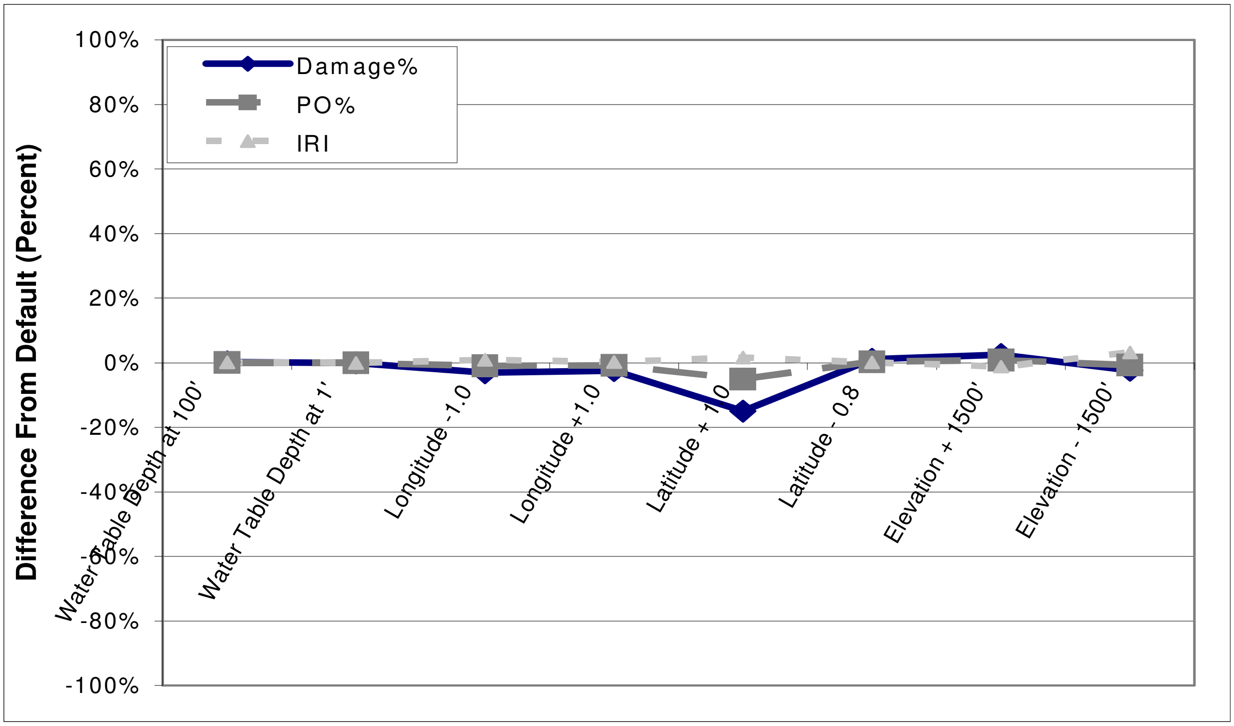

Figure I-3. Dry-Cold, CRCP, Climate Variables.

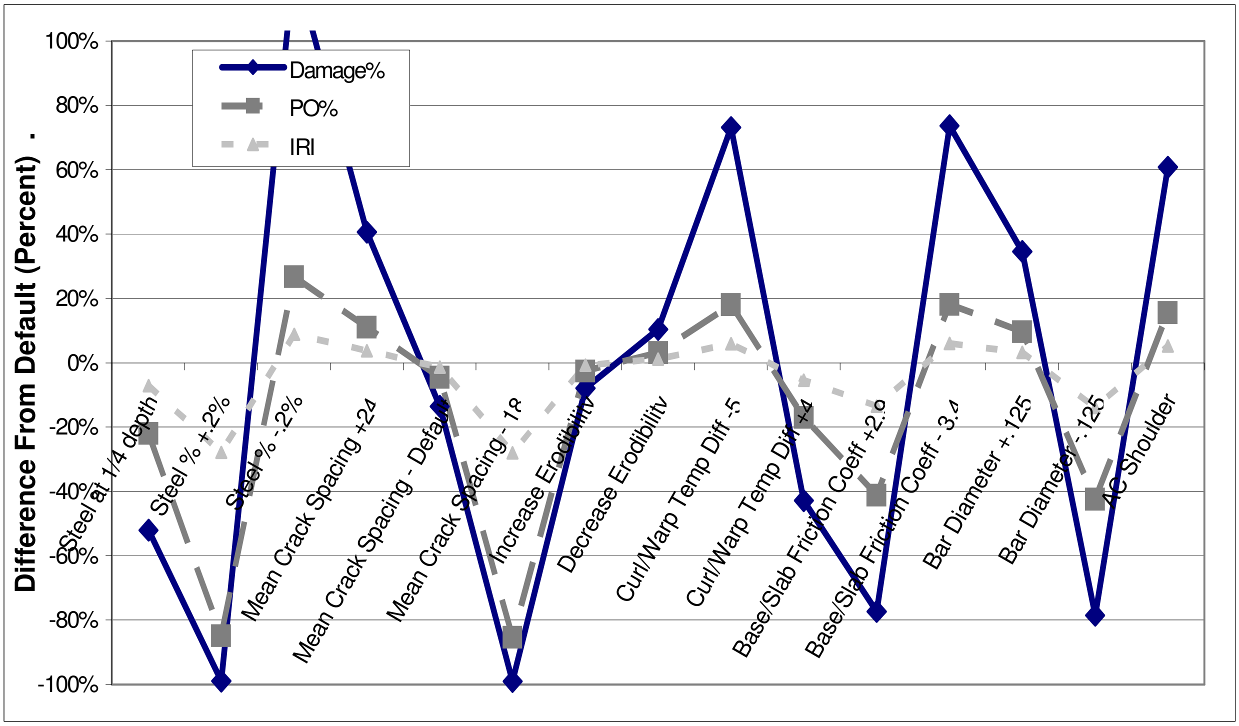

Figure I-4. Dry-Cold, CRCP, Design Variables.

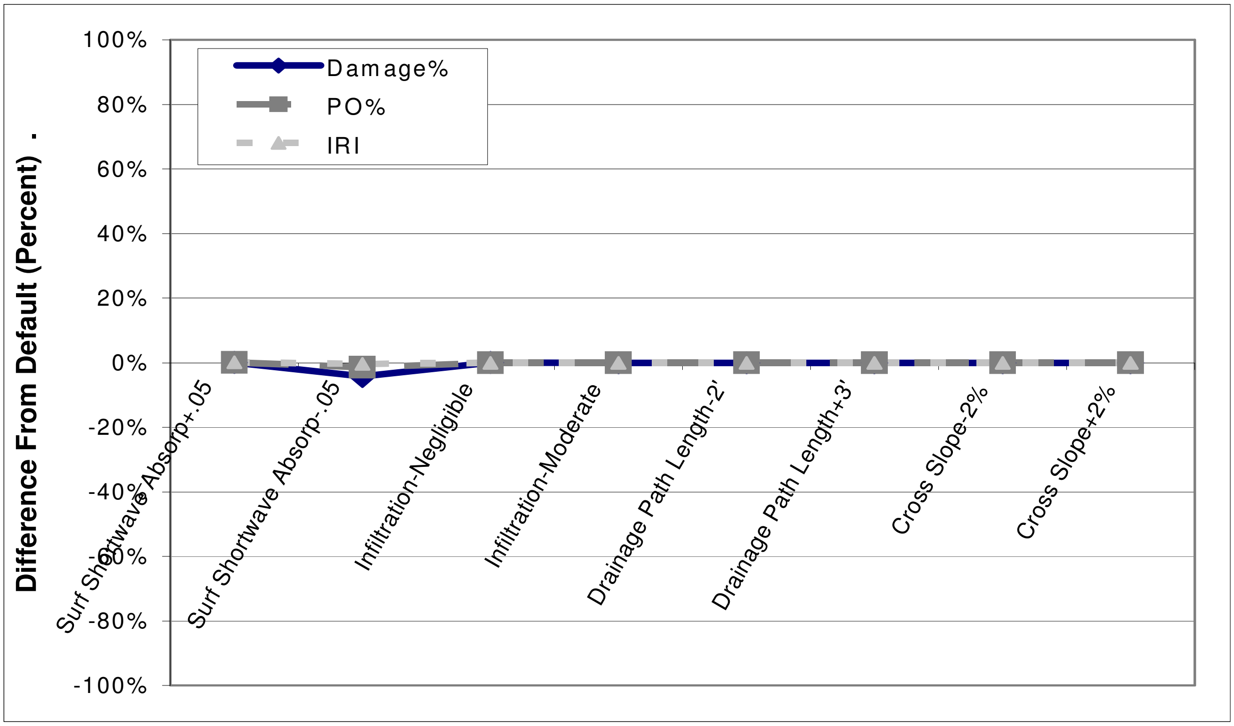

Figure I-5. Dry-Cold, CRCP, Drainage Variables.

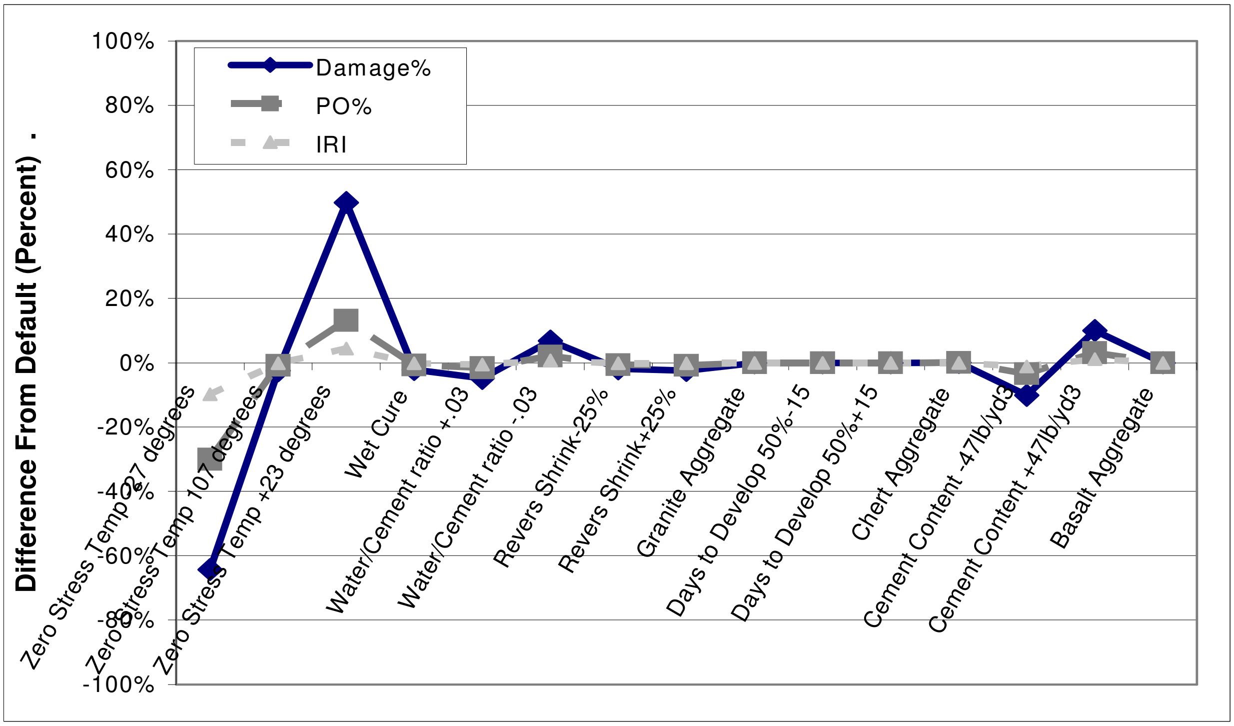

Figure I-6. Dry-Cold, CRCP, Mix Variables.

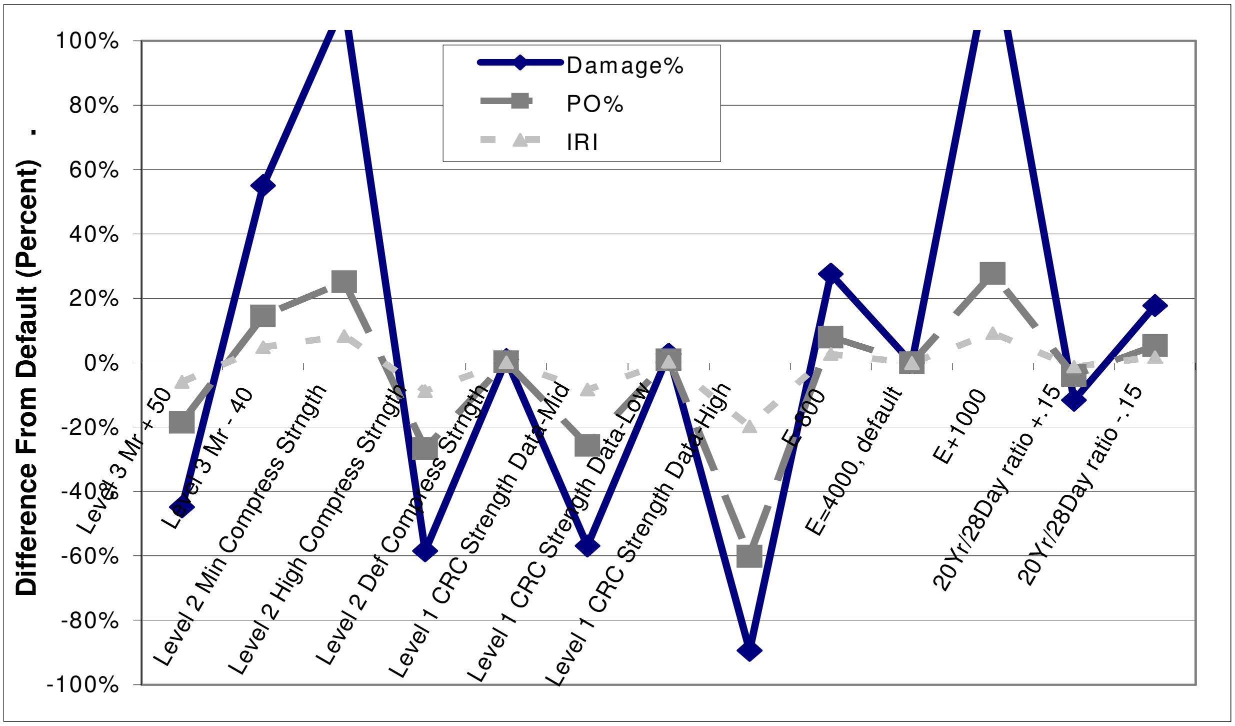

Figure I-7. Dry-Cold, CRCP, StrengthVariables.

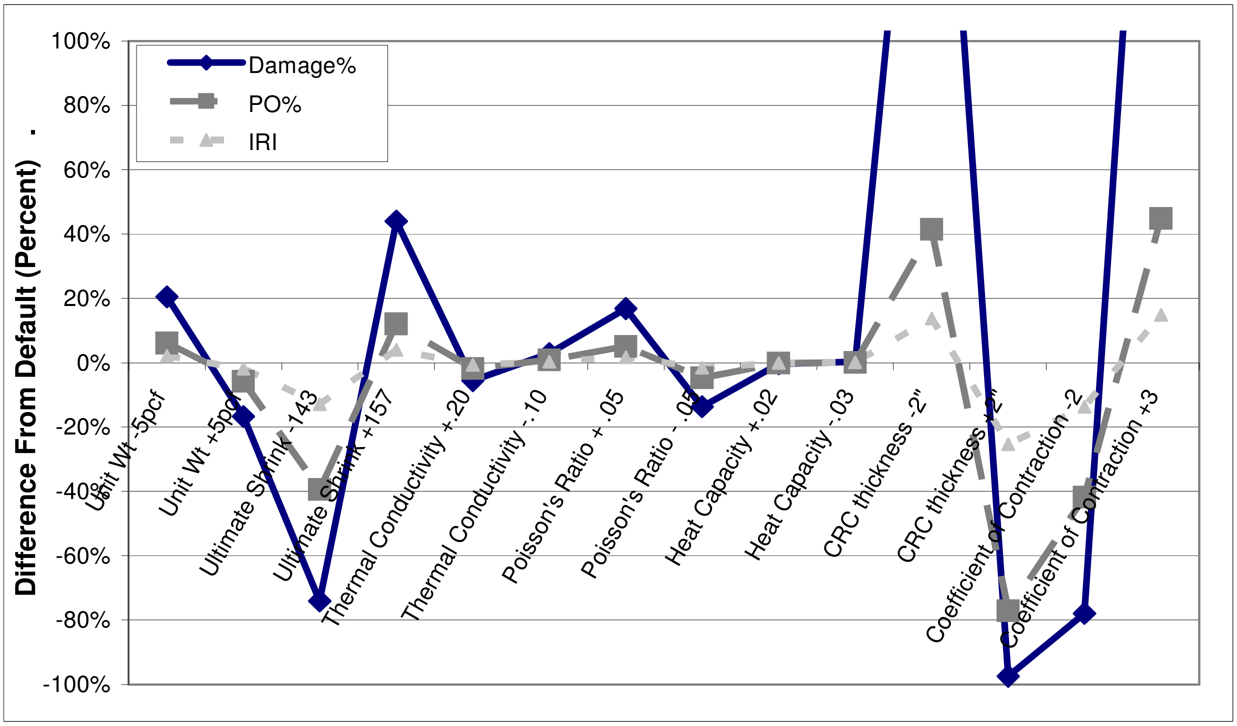

Figure I-8. Dry-Cold, CRCP, Thermal Variables.

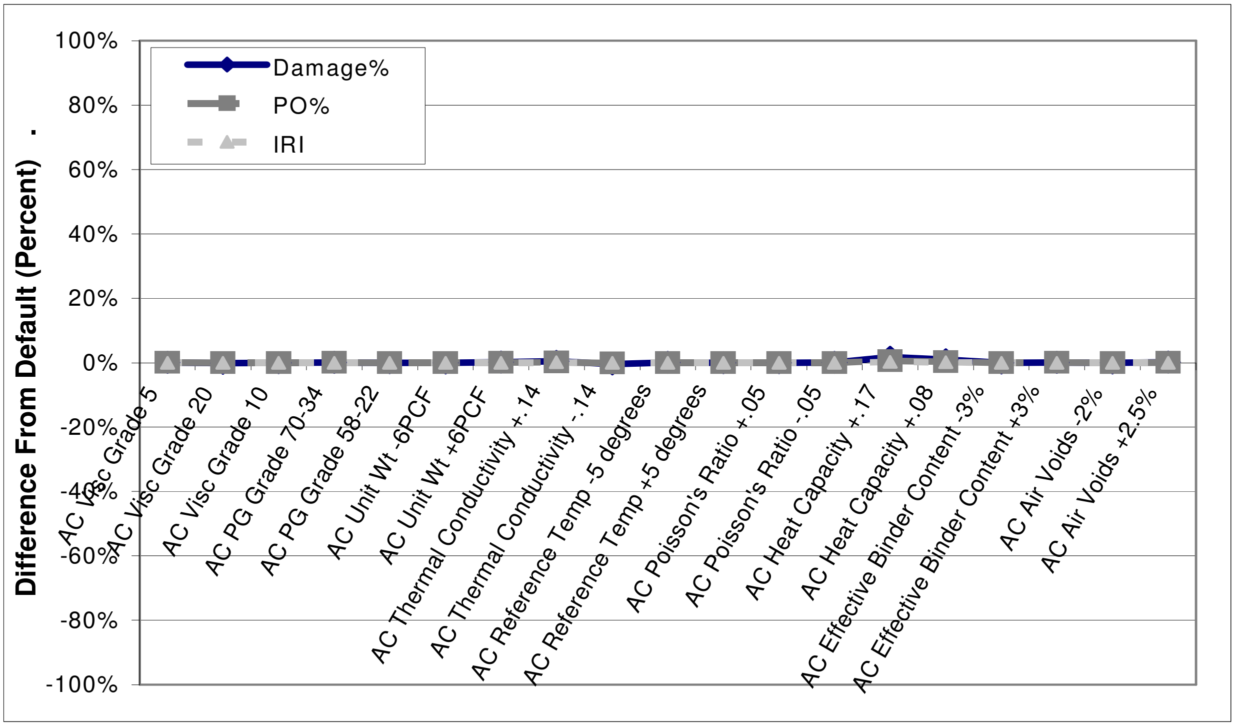

Figure I-9. Dry-Cold, CRCP, AC Layer Variables.

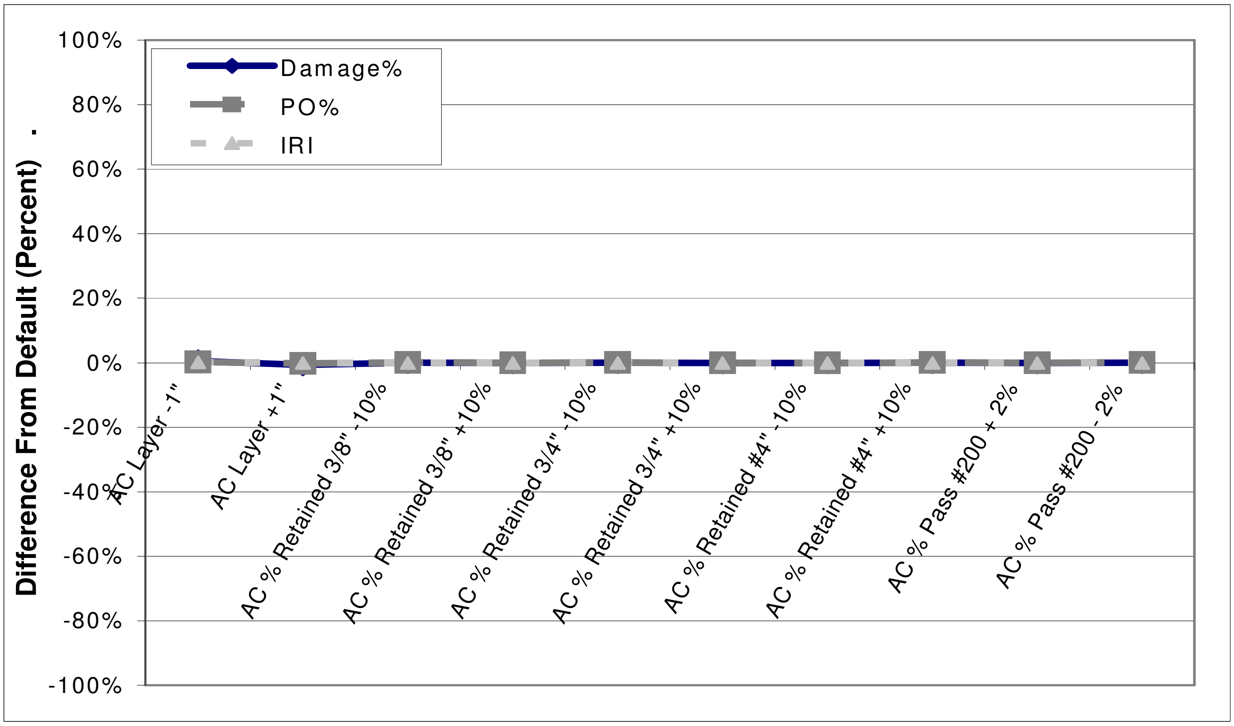

Figure I-10. Dry-Cold, CRCP, AC Mix Variables.

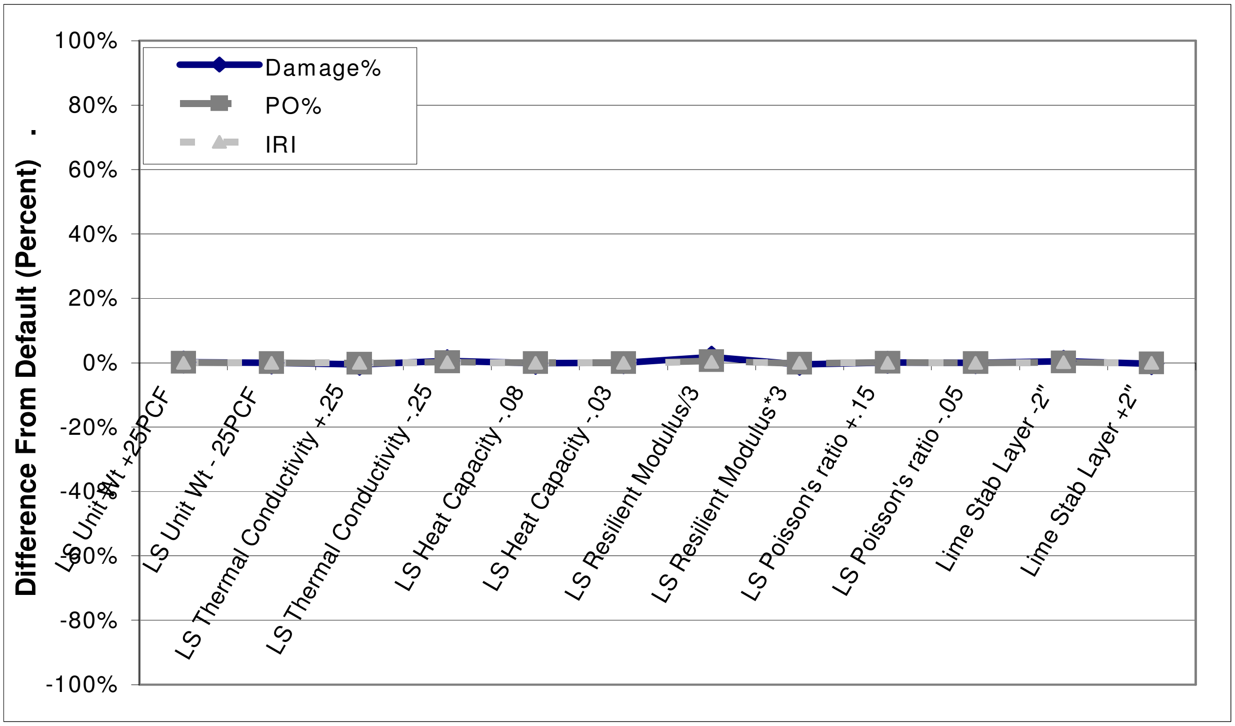

Figure I-11. Dry-Cold, CRCP, Lime Stabilized Variables.

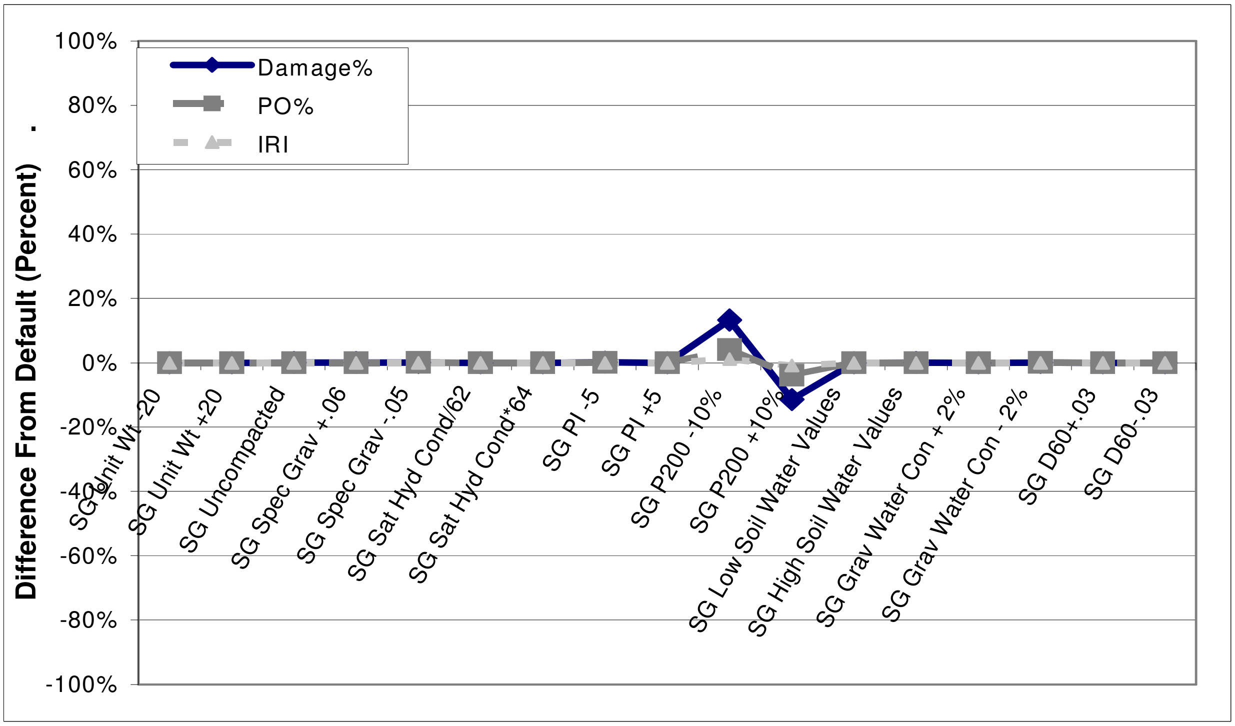

Figure I-12. Dry-Cold, CRCP, Subgrade ICM Variables.

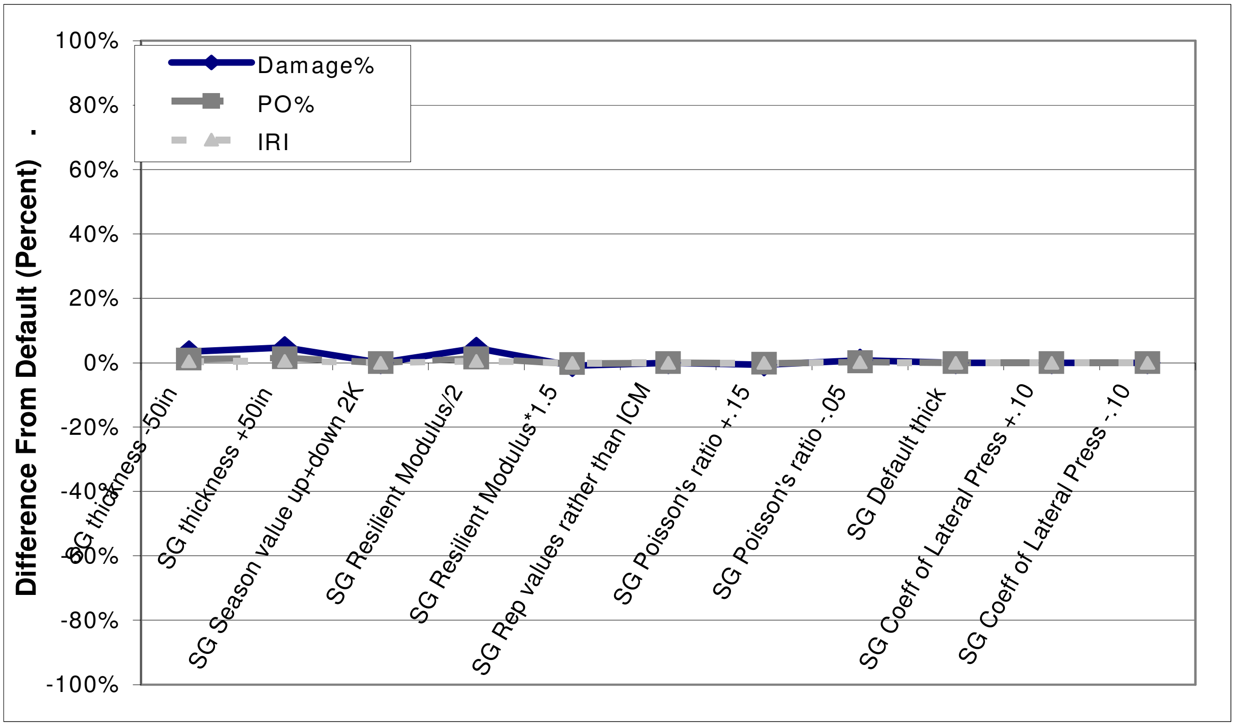

Figure I-13. Dry-Cold, CRCP, Subgrade Strength Variables.

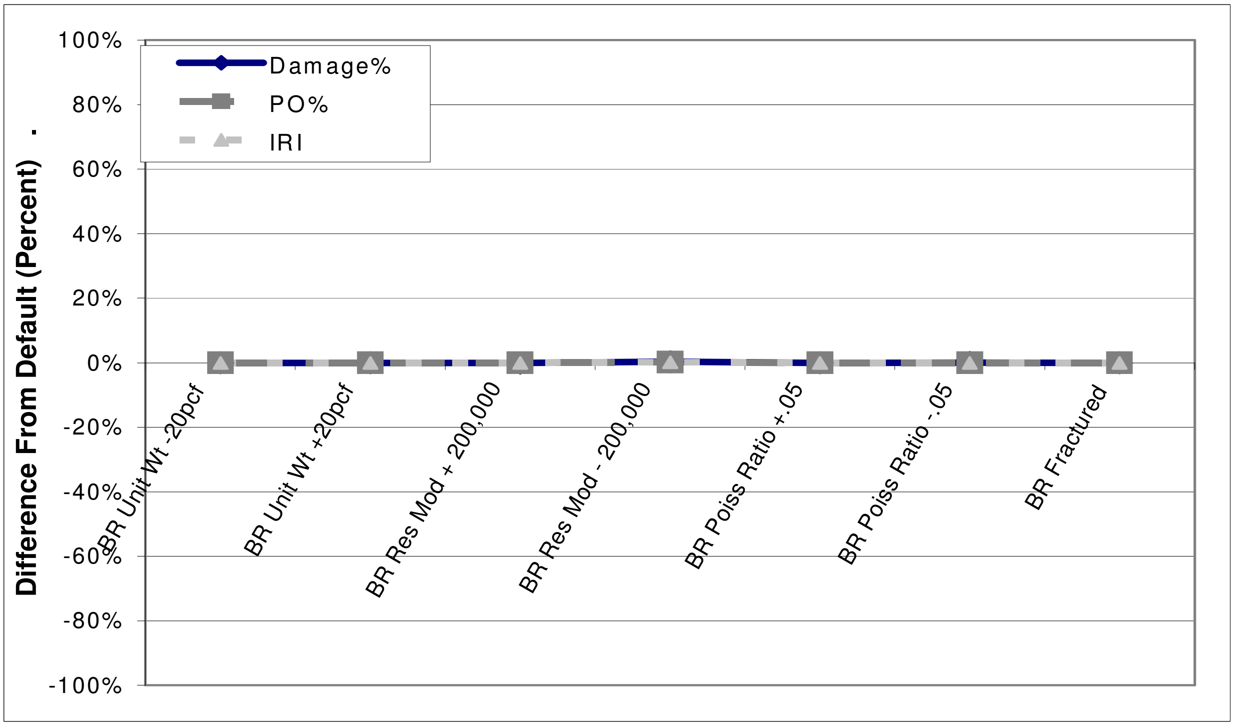

Figure I-14. Dry-Cold, CRCP, Bedrock Variables.

Table I-7. Results of Dry-Cold, CRCP, General Variables.

Description	Category	Damage%	PO%	IRI
Construction −5 month (Cold)	01-General	< < <	< < <	< < <
Construction +2 month (Hot)	01-General	>	>	>
Construction +4 month	01-General	< <	< < <	< < <
Traffic +4 month (More Cure)	01-General	>	>	>
Traffic −1 month (Less Cure)	01-General	<	<	=
Local Road	02-Site	=	=	=
Minor Arterial	02-Site	=	=	=

Table I-8. Results of Dry-Cold, CRCP, Traffic Variables.

Description	Category	Damage%	PO%	IRI
AADT −1600	03-Traffic	< <	< <	< <
AADT +1600	03-Traffic	> >	> >	> >
Lane Width 2' Less	03-Traffic-General	=	=	=
Lane Width 2' More	03-Traffic-General	=	=	=
Wander 2" Less	03-Traffic-General	<	< <	< <
Wander 2" More	03-Traffic-General	>	>	>
Wheel Loca 4" Close Ln Mrk	03-Traffic-General	> > >	> >	> >
Wheel Loca 4" Far Ln Mrk	03-Traffic-General	< <	< < <	< < <
ALL Tire Press +30 psi	03-Traffic-General-Axle	=	=	=
ALL Tire Press −30 psi	03-Traffic-General-Axle	=	=	=
Dual Tire Press +30 psi	03-Traffic-General-Axle	=	=	=
Dual Tire Press −30 psi	03-Traffic-General-Axle	=	=	=
Single Tire Press +30 psi	03-Traffic-General-Axle	=	=	=
Single Tire Press −30 psi	03-Traffic-General-Axle	=	=	=

Table I-9. Results of Dry-Cold, CRCP, Climate Variables.

Description	Category	Damage%	PO%	IRI
Elevation −1500'	04-Climate	<	<	> >
Elevation +1500'	04-Climate	>	>	<
Latitude −0.8	04-Climate	>	>	>
Latitude +1.0	04-Climate	<	<	>
Longitude +1.0	04-Climate	<	<	>
Longitude −1.0	04-Climate	<	<	>
Water Table Depth at 1'	04-Climate	=	=	=
Water Table Depth at 100'	04-Climate	>	=	>

Table I-10. Results of Dry-Cold, CRCP, DesignVariables.

Description	Category	Damage%	PO%	IRI
AC Shoulder	06-Design	> >	> >	> >
Bar Diameter −0.125	06-Design	< <	< < <	< < <
Bar Diameter +0.125	06-Design	> >	> >	> >
Base/Slab Friction Coeff −3.4	06-Design	> >	> >	> >
Base/Slab Friction Coeff +2.9	06-Design	< <	< < <	< < <
* Curl/Warp Temp Diff +4	06-Design	< <	< <	< <
* Curl/Warp Temp Diff −5	06-Design	> >	> >	> >
* Decrease Erodibility	06-Design	>	>	>
* Increase Erodibility	06-Design	<	<	<
Mean Crack Spacing −18"	06-Design	< < <	< < <	< < <
Mean Crack Spacing - Def	06-Design	<	<	<
Mean Crack Spacing +24"	06-Design	> >	> >	> >
Steel % −0.2%	06-Design	> > >	> >	> >
Steel % +0.2%	06-Design	< < <	< < <	< < <
Steel at 1/4 Depth	06-Design	< <	< <	< <

* - Trend seems inconsistent with engineering principles.

Table I-11. Results of Dry-Cold, CRCP, Drainage Variables.

Description	Category	Damage%	PO%	IRI
Cross Slope +2%	07-Drain	=	=	=
Cross Slope −2%	07-Drain	=	=	=
Drainage Path Length +3'	07-Drain	=	=	=
Drainage Path Length −2'	07-Drain	=	=	=
Infiltration-Moderate	07-Drain	=	=	=
Infiltration-Negligible	07-Drain	=	=	=
Surf Shortwave Absorp −0.05	07-Drain	<	<	<
Surf Shortwave Absorp +0.05	07-Drain	=	=	>

Table I-12. Results of Dry-Cold, CRCP, Mix Variables.

Description	Category	Damage%	PO%	IRI
Basalt Aggregate	08-CRC-Mix	=	=	=
Cement Content +47 lb/yd^3	08-CRC-Mix	>	>	>
Cement Content −47 lb/yd^3	08-CRC-Mix	<	<	<
Chert Aggregate	08-CRC-Mix	=	=	=
Days to Develop 50% +15	08-CRC-Mix	=	=	=
Days to Develop 50% −15	08-CRC-Mix	=	=	=
Granite Aggregate	08-CRC-Mix	=	=	=
* Revers Shrink +25%	08-CRC-Mix	<	<	<
* Revers Shrink −25%	08-CRC-Mix	<	<	<
* Water/Cement Ratio −0.03	08-CRC-Mix	>	>	>
* Water/Cement Ratio +0.03	08-CRC-Mix	<	<	<
Wet Cure	08-CRC-Mix	<	<	<
Zero Stress Temp +23 °F	08-CRC-Mix	>>	>>	>>
Zero Stress Temp 107 °F	08-CRC-Mix	<	<	<
Zero Stress Temp −27 °F	08-CRC-Mix	<<	<<<	<<<

* - Trend seems inconsistent with engineering principles.

Table I-13. Results of Dry-Cold, CRCP, Strength Variables.

	Description	Category	Damage%	PO%	IRI
	20Yr/28Day Ratio −0.15	08-CRC-Strength	> >	>	>
	20Yr/28Day Ratio +0.15	08-CRC-Strength	<	<	<
*	E +1000 ksi	08-CRC-Strength	> > >	> >	> >
	E =4000, Default	08-CRC-Strength	=	=	=
*	E −800 ksi	08-CRC-Strength	> >	> >	> >
	Level 1 CRC Strength Data-High	08-CRC-Strength	< < <	< < <	< < <
	Level 1 CRC Strength Data-Low	08-CRC-Strength	>	>	>
	Level 1 CRC Strength Data-Mid	08-CRC-Strength	< <	< <	< <
	Level 2 Def Compress Strength	08-CRC-Strength	>	>	>
	Level 2 High Compress Strength	08-CRC-Strength	< <	< <	< <
	Level 2 Min Compress Strength	08-CRC-Strength	> > >	> >	> >
	Level 3 Mr −40 psi	08-CRC-Strength	> >	> >	> >
	Level 3 Mr +50 psi	08-CRC-Strength	< <	< <	< <

* - Trend seems inconsistent with engineering principles.

Table I-14. Results of Dry-Cold, CRCP, Thermal Variables.

Description	Category	Damage%	PO%	IRI
Coefficient of Contraction +3	08-CRC-Thermal	> > >	> > >	> > >
Coefficient of Contraction −2	08-CRC-Thermal	< <	< < <	< < <
CRC Thickness +2"	08-CRC-Thermal	< < <	< < <	< < <
CRC Thickness −2"	08-CRC-Thermal	> > >	> > >	> > >
Heat Capacity −0.03	08-CRC-Thermal	>	=	>
Heat Capacity +0.02	08-CRC-Thermal	<	<	=
Poisson’s Ratio −0.05	08-CRC-Thermal	<	<	<
Poisson’s Ratio +0.05	08-CRC-Thermal	>	>	>
Thermal Conductivity −0.10	08-CRC-Thermal	>	>	>
Thermal Conductivity +0.20	08-CRC-Thermal	<	<	<
Ultimate Shrink +157 psi	08-CRC-Thermal	> >	> >	> >
Ultimate Shrink −143 psi	08-CRC-Thermal	< <	< < <	< < <
Unit Wt +5 pcf	08-CRC-Thermal	<	< <	< <
Unit Wt −5 pcf	08-CRC-Thermal	> >	> >	> >

Table I-15. Results of Dry-Cold, CRCP, AC Binder Variables.

Description	Category	Damage%	PO%	IRI
AC PG Grade 58-22	09-AC-Binder	=	=	=
AC PG Grade 70-34	09-AC-Binder	=	=	=
AC Visc Grade 10	09-AC-Binder	=	=	=
AC Visc Grade 20	09-AC-Binder	<	=	=
AC Visc Grade 5	09-AC-Binder	=	=	=

Table I-16. Results of Dry-Cold, CRCP, AC General Variables.

Description	Category	Damage%	PO%	IRI
AC Air Voids +2.5%	09-AC-General	>	=	=
AC Air Voids −2%	09-AC-General	<	=	=
AC Effective Binder Content +3%	09-AC-General	=	=	=
AC Effective Binder Content −3%	09-AC-General	<	=	=
AC Heat Capacity +0.08	09-AC-General	>	>	>
AC Heat Capacity +0.17	09-AC-General	>	>	>
AC Poisson’s Ratio −0.05	09-AC-General	=	=	=
AC Poisson’s Ratio +0.05	09-AC-General	=	=	=
AC Reference Temp +5 °F	09-AC-General	=	=	=
AC Reference Temp −5 °F	09-AC-General	=	=	=
AC Thermal Conductivity −0.14	09-AC-General	<	<	=
AC Thermal Conductivity +0.14	09-AC-General	>	>	>
AC Unit Wt +6 pcf	09-AC-General	>	=	=
AC Unit Wt −6 pcf	09-AC-General	<	=	=

Table I-17. Results of Dry-Cold, CRCP, AC Mix Variables.

Description	Category	Damage%	PO%	IRI
AC % Pass #200 −2%	09-AC-Mix	=	=	=
AC % Pass #200 +2%	09-AC-Mix	=	=	=
AC % Retained #4 +10%	09-AC-Mix	=	=	=
AC % Retained #4 −10%	09-AC-Mix	=	=	=
AC % Retained 3/4" +10%	09-AC-Mix	=	=	=
AC % Retained 3/4" −10%	09-AC-Mix	=	=	=
AC % Retained 3/8" +10%	09-AC-Mix	=	=	=
AC % Retained 3/8" −10%	09-AC-Mix	=	=	=
AC Layer +1"	09-AC-Mix	<	<	=
AC Layer −1"	09-AC-Mix	>	>	>

Table I-18. Results of Dry-Cold, CRCP, Lime Stabilized ICM Variables.

Description	Category	Damage %	PO%	IRI
LS Heat Capacity −0.03	10-LS-ICM	=	=	=
LS Heat Capacity −0.08	10-LS-ICM	<	=	=
LS Thermal Conductivity −0.25	10-LS-ICM	>	>	>
LS Thermal Conductivity +0.25	10-LS-ICM	<	<	=
LS Unit Wt −25 pcf	10-LS-ICM	<	=	=
LS Unit Wt +25 pcf	10-LS-ICM	>	=	=

Table I-19. Results of Dry-Cold, CRCP, Lime Stabilized Strength Variables.

Description	Category	Damage%	PO%	IRI
Lime Stab Layer +2"	10-LS-Strength	<	<	=
Lime Stab Layer −2"	10-LS-Strength	>	>	>
LS Poisson’s Ratio −0.05	10-LS-Strength	=	=	=
LS Poisson’s Ratio +0.15	10-LS-Strength	=	=	=
LS Resilient Modulus×3	10-LS-Strength	<	<	=
LS Resilient Modulus/3	10-LS-Strength	>	>	>

Table I-20. Results of Dry-Cold, CRCP, Subgrade ICM Variables.

Description	Category	Damage %	PO%	IRI
SG D60 −0.03	11-SG-ICM	=	=	=
SG D60 +0.03	11-SG-ICM	=	=	=
SG Grav Water Con −2%	11-SG-ICM	=	=	=
SG Grav Water Con +2%	11-SG-ICM	=	=	=
SG High Soil Water Values	11-SG-ICM	=	=	=
SG Low Soil Water Values	11-SG-ICM	=	=	=
SG P200 +10%	11-SG-ICM	<	<	<
SG P200 −10%	11-SG-ICM	>	>	>
SG PI +5	11-SG-ICM	=	=	=
SG PI −5	11-SG-ICM	=	=	=
SG Sat Hyd Cond×64	11-SG-ICM	=	=	=
SG Sat Hyd Cond/62	11-SG-ICM	=	=	=
SG Spec Grav −0.05	11-SG-ICM	=	=	=
SG Spec Grav +0.06	11-SG-ICM	=	=	=
SG Uncompacted	11-SG-ICM	=	=	=
SG Unit Wt +20 pcf	11-SG-ICM	=	=	=
SG Unit Wt −20 pcf	11-SG-ICM	=	=	=

Table I-21. Results of Dry-Cold, CRCP, Subgrade Strength Variables.

Description	Category	Damage%	PO%	IRI
SG Coeff of Lateral Press −0.10	11-SG-Strength	=	=	=
SG Coeff of Lateral Press +0.10	11-SG-Strength	=	=	=
SG Default Thick	11-SG-Strength	=	=	=
SG Poisson's Ratio −0.05	11-SG-Strength	>	>	>
SG Poisson's Ratio +0.15	11-SG-Strength	<	<	<
SG Rep Values Rather than ICM	11-SG-Strength	=	=	=
SG Resilient Modulus*1.5	11-SG-Strength	<	<	<
SG Resilient Modulus/2	11-SG-Strength	>	>	>
SG Season Value Up+Down 2K	11-SG-Strength	=	=	=
SG Thickness +50"	11-SG-Strength	>	>	>
SG Thickness −50"	11-SG-Strength	>	>	>

Table I-22. Results of Dry-Cold, CRCP, Bedrock Variables.

Description	Category	Damage%	PO%	IRI
BR Fractured	12-BR	=	=	=
BR Poiss Ratio −0.05	12-BR	=	=	=
BR Poiss Ratio +0.05	12-BR	=	=	=
BR Res Mod −200,000	12-BR	>	=	>
BR Res Mod +200,000	12-BR	<	=	=
BR Unit Wt +20 pcf	12-BR	=	=	=
BR Unit Wt −20 pcf	12-BR	=	=	=

APPENDIX J

WET-WARM, CRCP RESULTS

Table J-1. Wet-Warm, CRCP, Highly Significant Variables - Damage.

Description	Category	Damage
Wheel Loca 4" Close Lane Mark	03-Traffic-General	0.4
Wheel Loca 4" Far Lane Mark	03-Traffic-General	0.5
Base/Slab Friction Coeff −3.4	06-Design	0.0
Curl/Warp Temp Diff +4	06-Design	0.3
Curl/Warp Temp Diff −5	06-Design	0.1
Steel % −0.2%	06-Design	0.2
Zero Stress Temp +23 °F	08-CRC-Mix	0.0
E +1000 ksi	08-CRC-Strength	0.0
Level 1 CRC Strength Data-High	08-CRC-Strength	0.2
Level 1 CRC Strength Data-Low	08-CRC-Strength	0.3
Level 1 CRC Strength Data-Mid	08-CRC-Strength	0.2
Level 2 Hig Compress Strength	08-CRC-Strength	0.2
Level 2 Min Compress Strength	08-CRC-Strength	0.0
Level 3 Mr −40 psi	08-CRC-Strength	0.1
Level 3 Mr +50 psi	08-CRC-Strength	0.3
Coefficient of Contraction +3	08-CRC-Thermal	0.0
Coefficient of Contraction −2	08-CRC-Thermal	0.2
CRC Thickness +2"	08-CRC-Thermal	0.3
CRC Thickness −2"	08-CRC-Thermal	0.0
Poisson’s Ratio −0.05	08-CRC-Thermal	0.5
SG Grav Water Con −10%	12-SG-ICM	0.0
SG High Soil Water Values	12-SG-ICM	0.2
SG Low Soil Water Values	12-SG-ICM	0.3
SG Spec Grav +0.10	12-SG-ICM	0.0
SG Unit Wt +23 pcf	12-SG-ICM	0.5
SG Unit Wt −17 pcf	12-SG-ICM	0.0
SG Poisson’s Ratio +0.05	12-SG-Strength	0.4
SG Resilient Modulus +3 ksi	12-SG-Strength	0.4
SG Resilient Modulus −3 ksi	12-SG-Strength	0.5
SG Thickness +50"	12-SG-Strength	0.3

Table J-2. Wet-Warm, CRCP, Significant Variables - Damage.

Description	Category	Damage
AADT −1600 (20%)	03-Traffic	1.0
AADT +1600 (20%)	03-Traffic	1.0
Wander 2" Less	03-Traffic-General	1.0
Wander 2" More	03-Traffic-General	1.5
Latitude −0.9	04-Climate	1.4
Longitude +0.7	04-Climate	1.3
Water Table Depth at 1'	04-Climate	1.4
Water Table Depth at 50'	04-Climate	1.3
Surf Shortwave Absorp −0.05	07-Drain	1.9
Surf Shortwave Absorp +0.05	07-Drain	1.7
20Yr/28Day Ratio −0.15	08-CRC-Strength	1.3
20Yr/28Day Ratio +0.15	08-CRC-Strength	0.6
Level 2 Def Compress Strength	08-CRC-Strength	1.6
Poisson's Ratio +0.05	08-CRC-Thermal	0.9
Thermal Conductivity −0.10	08-CRC-Thermal	2.1
Thermal Conductivity +0.20	08-CRC-Thermal	1.3
Unit Wt +5pcf	08-CRC-Thermal	0.5
Unit Wt −5pcf	08-CRC-Thermal	1.3
AC Layer +1"	09-AC-Mix	1.6
Cement Stab Layer +1"	10-CS-Strength	1.4
Cement Stab Layer −1"	10-CS-Strength	1.6
CS Resilient Modulus×2	10-CS-Strength	0.7
CS Resilient Modulus/2	10-CS-Strength	1.3
Lime Stab Layer +2"	11-LS-Strength	2.0
Lime Stab Layer −2"	11-LS-Strength	2.3
LS Resilient Modulus×3	11-LS-Strength	0.7
LS Resilient Modulus/3	11-LS-Strength	0.7
SG Grav Water Con +10%	12-SG-ICM	0.6
SG Poisson's Ratio −0.05	12-SG-Strength	0.9

Table J-3. Wet-Warm, CRCP, Highly Significant Variables - Punchouts.

Description	Category	30Yr PO
Wheel Loca 4" Close Lane Mark	03-Traffic-General	0.4
Wheel Loca 4" Far Lane Mark	03-Traffic-General	0.4
Base/Slab Friction Coeff −3.4	06-Design	0.0
Curl/Warp Temp Diff +4 °F	06-Design	0.2
Curl/Warp Temp Diff −5 °F	06-Design	0.1
Steel % −0.2%	06-Design	0.2
Zero Stress Temp +23 °F	08-CRC-Mix	0.0
20Yr/28Day Ratio +0.15	08-CRC-Strength	0.5
E +1000 ksi	08-CRC-Strength	0.1
Level 1 CRC Strength Data-High	08-CRC-Strength	0.2
Level 1 CRC Strength Data-Low	08-CRC-Strength	0.2
Level 1 CRC Strength Data-Mid	08-CRC-Strength	0.1
Level 2 Hig Compress Strength	08-CRC-Strength	0.1
Level 2 Min Compress Strength	08-CRC-Strength	0.1
Level 3 Mr −40 psi	08-CRC-Strength	0.2
Level 3 Mr +50 psi	08-CRC-Strength	0.2
Coefficient of Contraction +3	08-CRC-Thermal	0.1
Coefficient of Contraction −2	08-CRC-Thermal	0.1
CRC Thickness +2"	08-CRC-Thermal	0.2
CRC Thickness −2"	08-CRC-Thermal	0.0
Poisson’s Ratio −0.05	08-CRC-Thermal	0.4
Unit Wt +5 pcf	08-CRC-Thermal	0.5
SG Grav Water Con −10%	12-SG-ICM	0.1
SG High Soil Water Values	12-SG-ICM	0.2
SG Low Soil Water Values	12-SG-ICM	0.4
SG Spec Grav +0.10	12-SG-ICM	0.1
SG Unit Wt −17 pcf	12-SG-ICM	0.1
SG Resilient Modulus −3 ksi	12-SG-Strength	0.4
SG Thickness +50"	12-SG-Strength	0.2

Table J-4. Wet-Warm, CRCP, Significant Variables - Punchouts.

Description	Category	30Yr PO
AADT −1600 (20%)	03-Traffic	0.9
AADT +1600 (20%)	03-Traffic	1.1
Wander 2" Less	03-Traffic-General	0.9
Wander 2" More	03-Traffic-General	1.6
Latitude −0.9	04-Climate	1.4
Longitude +0.7	04-Climate	1.2
Water Table Depth at 1'	04-Climate	1.4
Water Table Depth at 50'	04-Climate	1.3
Surf Shortwave Absorp −0.05	07-Drain	1.8
Surf Shortwave Absorp +0.05	07-Drain	1.8
20Yr/28Day Ratio −0.15	08-CRC-Strength	1.4
Level 2 Def Compress Strength	08-CRC-Strength	1.5
Poisson’s Ratio +0.05	08-CRC-Thermal	0.9
Thermal Conductivity −0.10	08-CRC-Thermal	2.2
Thermal Conductivity +0.20	08-CRC-Thermal	1.2
Unit Wt −5 pcf	08-CRC-Thermal	1.3
AC Layer +1"	09-AC-Mix	1.6
Cement Stab Layer +1"	10-CS-Strength	1.4
Cement Stab Layer −1"	10-CS-Strength	1.5
CS Resilient Modulus×2	10-CS-Strength	0.8
CS Resilient Modulus/2	10-CS-Strength	1.2
Lime Stab Layer +2"	11-LS-Strength	2.0
Lime Stab Layer −2"	11-LS-Strength	2.2
LS Resilient Modulus×3	11-LS-Strength	0.8
LS Resilient Modulus/3	11-LS-Strength	0.6
SG Grav Water Con +10%	12-SG-ICM	0.7
SG Unit Wt +23 pcf	12-SG-ICM	0.5
SG Poisson’s Ratio −0.05	12-SG-Strength	0.9
SG Poisson’s Ratio +0.05	12-SG-Strength	0.5
SG Resilient Modulus+3 ksi	12-SG-Strength	0.5

Table J-5. Wet-Warm, CRCP, Highly Significant Variables - IRI.

Description	Category	IRI
Wheel Loca 4" Close Lane Mark	03-Traffic-General	0.4
Wheel Loca 4" Far Lane Mark	03-Traffic-General	0.4
Base/Slab Friction Coeff −3.4	06-Design	0.0
Curl/Warp Temp Diff +4 °F	06-Design	0.2
Curl/Warp Temp Diff −5 °F	06-Design	0.1
Steel % −0.2%	06-Design	0.2
Zero Stress Temp +23 °F	08-CRC-Mix	0.0
20Yr/28Day Ratio +0.15	08-CRC-Strength	0.5
E +1000 ksi	08-CRC-Strength	0.1
Level 1 CRC Strength Data-High	08-CRC-Strength	0.2
Level 1 CRC Strength Data-Low	08-CRC-Strength	0.2
Level 1 CRC Strength Data-Mid	08-CRC-Strength	0.1
Level 2 Hig Compress Strength	08-CRC-Strength	0.1
Level 2 Min Compress Strength	08-CRC-Strength	0.1
Level 3 Mr −40 psi	08-CRC-Strength	0.2
Level 3 Mr +50 psi	08-CRC-Strength	0.2
Coefficient of Contraction +3	08-CRC-Thermal	0.1
Coefficient of Contraction −2	08-CRC-Thermal	0.1
CRC Thickness +2"	08-CRC-Thermal	0.2
CRC Thickness −2"	08-CRC-Thermal	0.0
Poisson's Ratio −0.05	08-CRC-Thermal	0.4
Unit Wt +5 pcf	08-CRC-Thermal	0.5
SG Grav Water Con −10%	12-SG-ICM	0.1
SG High Soil Water Values	12-SG-ICM	0.2
SG Low Soil Water Values	12-SG-ICM	0.4
SG Spec Grav +0.10	12-SG-ICM	0.1
SG Unit Wt −17 pcf	12-SG-ICM	0.1
SG Resilient Modulus −3 ksi	12-SG-Strength	0.4
SG Thickness +50"	12-SG-Strength	0.2

Table J-6. Wet-Warm, CRCP, Significant Variables - IRI.

Description	Category	IRI
AADT −1600 (20%)	03-Traffic	0.9
AADT +1600 (20%)	03-Traffic	1.1
Wander 2" Less	03-Traffic-General	0.9
Wander 2" More	03-Traffic-General	1.5
Latitude 0.9	04-Climate	1.3
Longitude +0.7	04-Climate	1.2
Water Table Depth at 1'	04-Climate	1.3
Water Table Depth at 50'	04-Climate	1.4
Surf Shortwave Absorp −0.05	07-Drain	1.7
Surf Shortwave Absorp +0.05	07-Drain	1.9
20Yr/28Day Ratio −0.15	08-CRC-Strength	1.4
Level 2 Def Compress Strength	08-CRC-Strength	1.4
Poisson's Ratio +0.05	08-CRC-Thermal	1.0
Thermal Conductivity −0.10	08-CRC-Thermal	2.1
Thermal Conductivity +0.20	08-CRC-Thermal	1.1
Unit Wt −5 pcf	08-CRC-Thermal	1.4
AC Layer +1"	09-AC-Mix	1.7
Cement Stab Layer +1"	10-CS-Strength	1.4
Cement Stab Layer −1"	10-CS-Strength	1.4
CS Resilient Modulus×2	10-CS-Strength	0.8
CS Resilient Modulus/2	10-CS-Strength	1.1
Lime Stab Layer +2"	11-LS-Strength	2.1
Lime Stab Layer −2"	11-LS-Strength	2.1
LS Resilient Modulus×3	11-LS-Strength	0.8
LS Resilient Modulus/3	11-LS-Strength	0.6
SG Grav Water Con +10%	12-SG-ICM	0.7
SG Unit Wt +23 pcf	12-SG-ICM	0.5
SG Poisson's Ratio −0.05	12-SG-Strength	0.8
SG Poisson's Ratio +0.05	12-SG-Strength	0.5
SG Resilient Modulus +3 ksi	12-SG-Strength	0.5

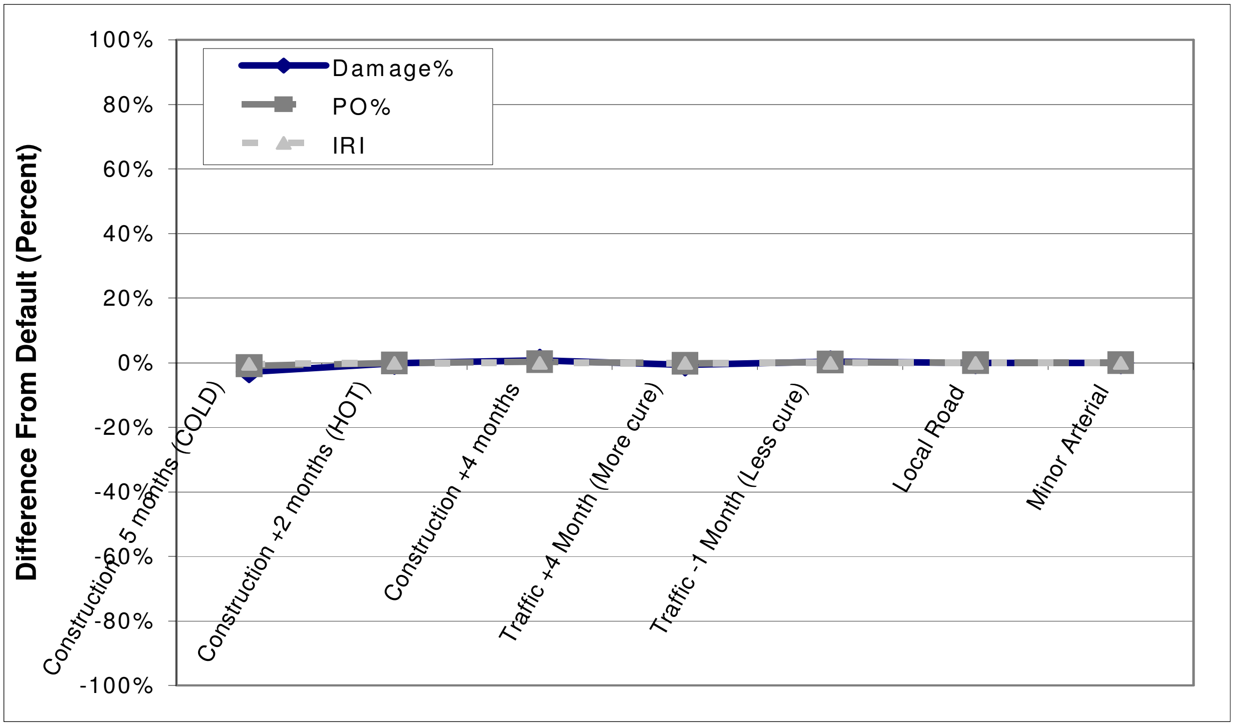

Figure J-1. Wet-Warm, CRCP, General Variables.

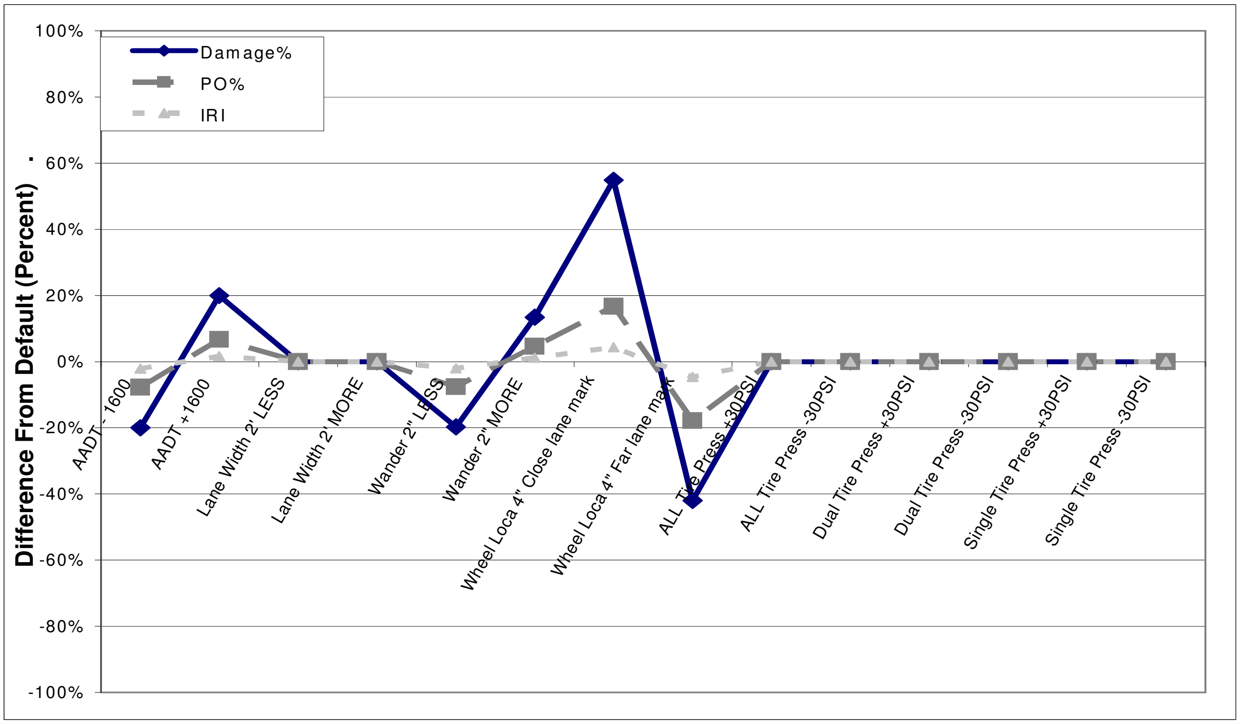

Figure J-2. Wet-Warm, CRCP, Traffic Variables.

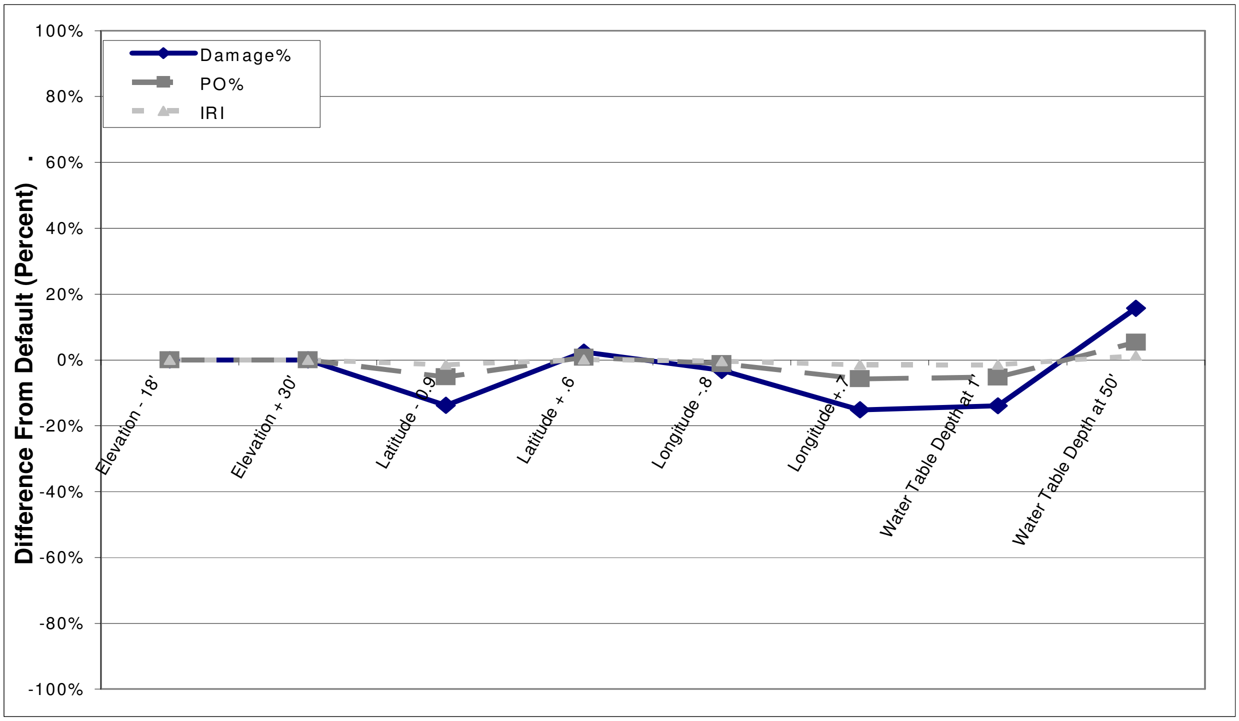

Figure J-3. Wet-Warm, CRCP, Climate Variables.

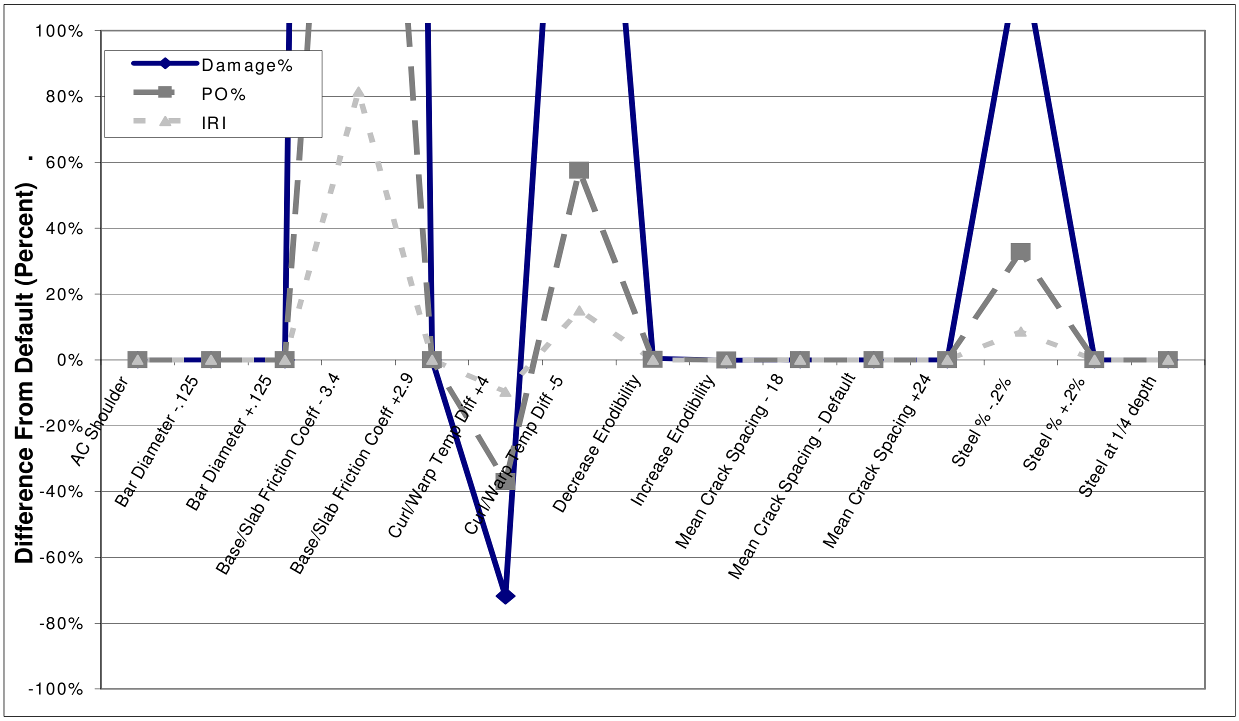

Figure J-4. Wet-Warm, CRCP, Design Variables.

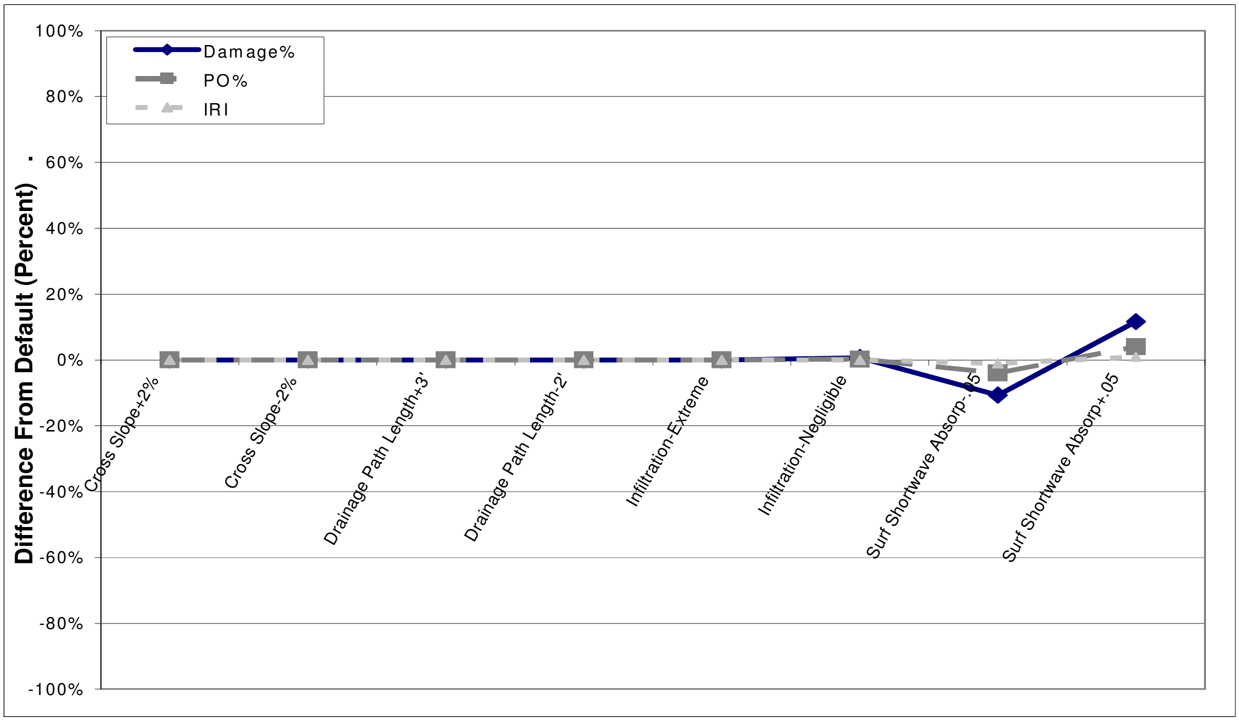

Figure J-5. Wet-Warm, CRCP, Drainage Variables.

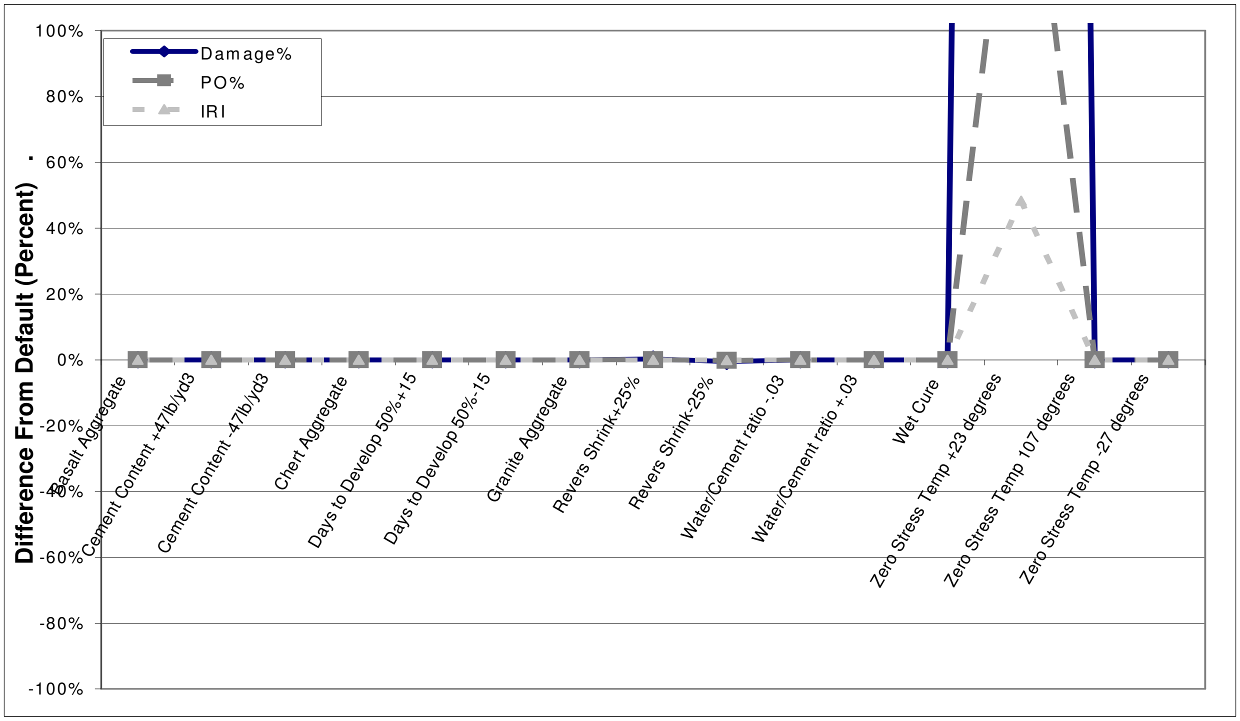

Figure J-6. Wet-Warm, CRCP, Mix Variables.

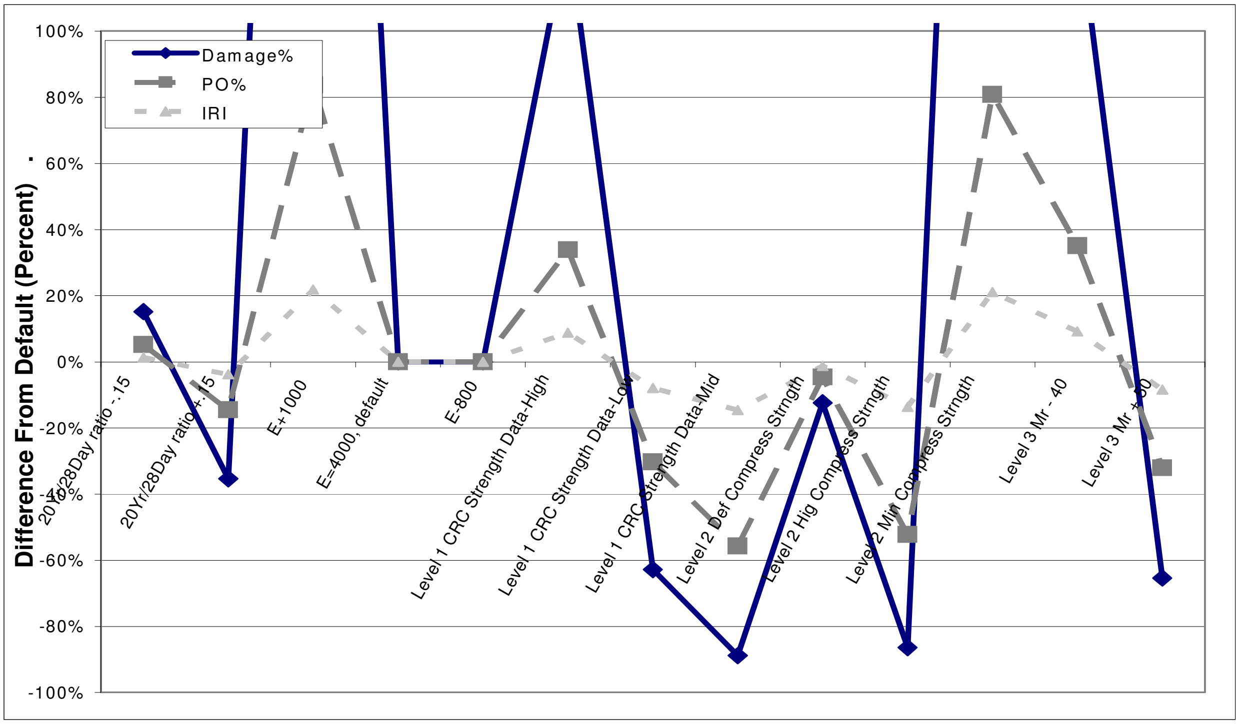

Figure J-7. Wet-Warm, CRCP, StrengthVariables.

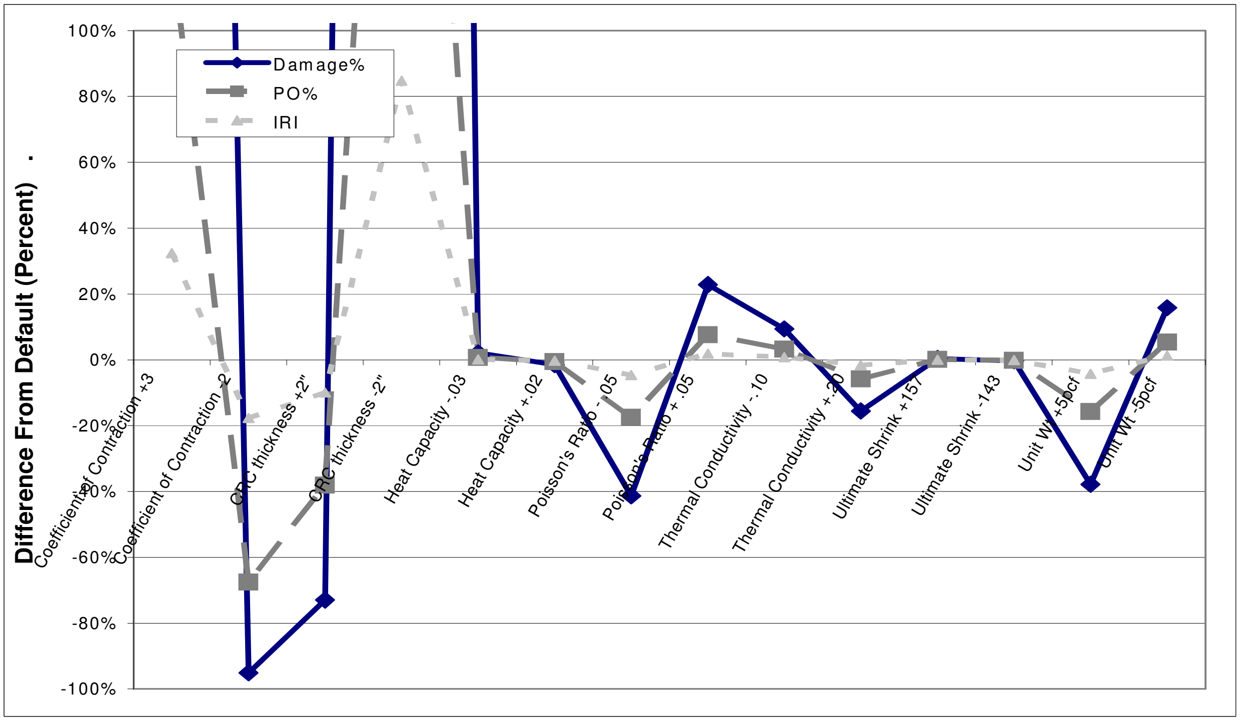

Figure J-8. Wet-Warm, CRCP, Thermal Variables.

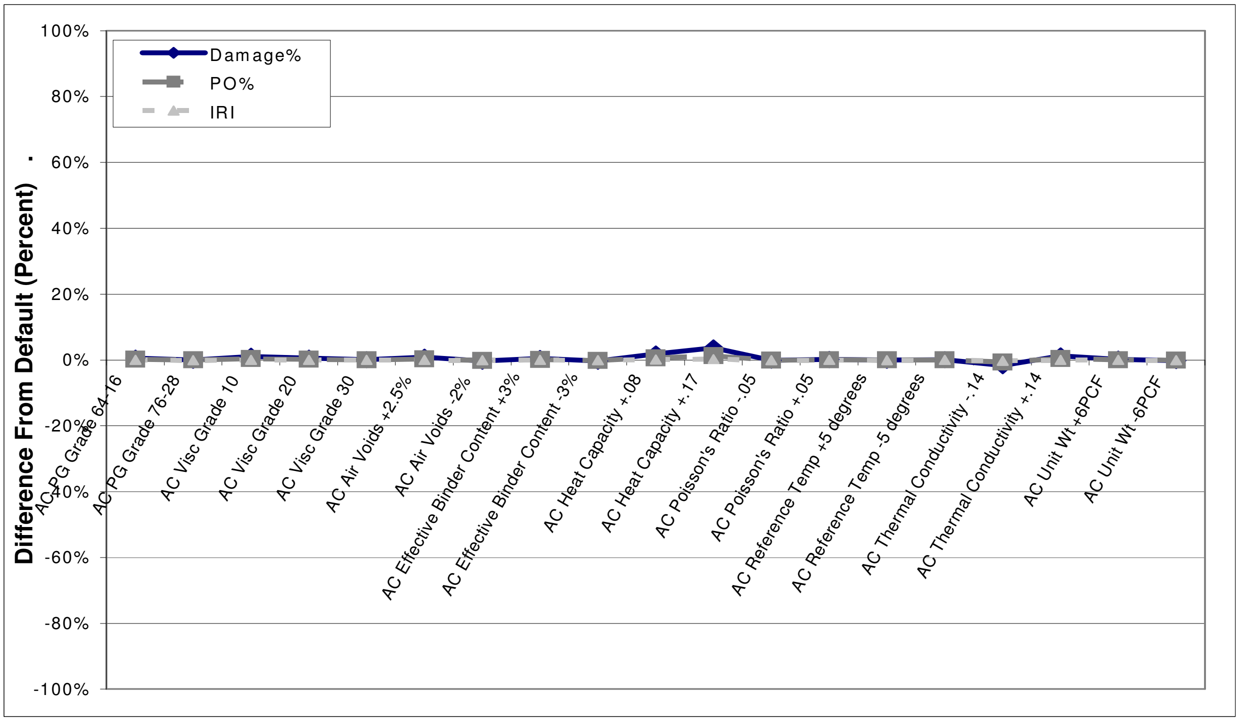

Figure J-9. Wet-Warm, CRCP, AC Layer Variables.

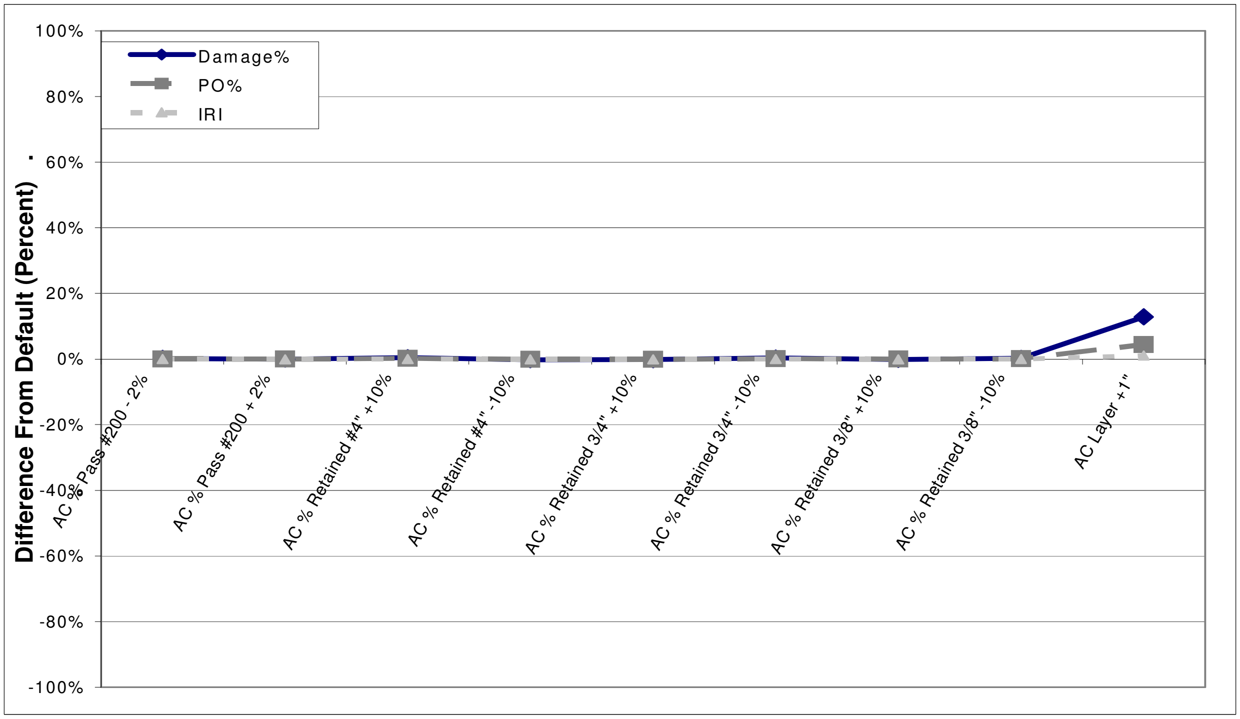

Figure J-10. Wet-Warm, CRCP, AC Mix Variables.

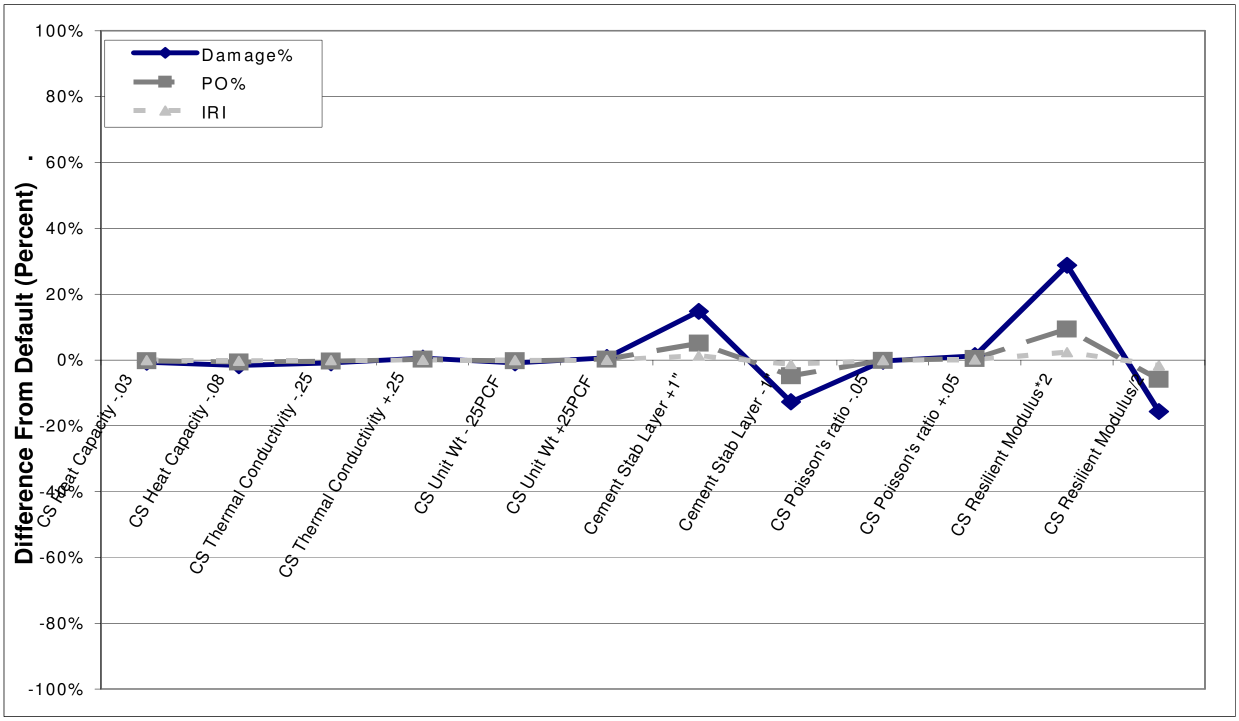

Figure J-11. Wet-Warm, CRCP, Cement Stabilized Variables.

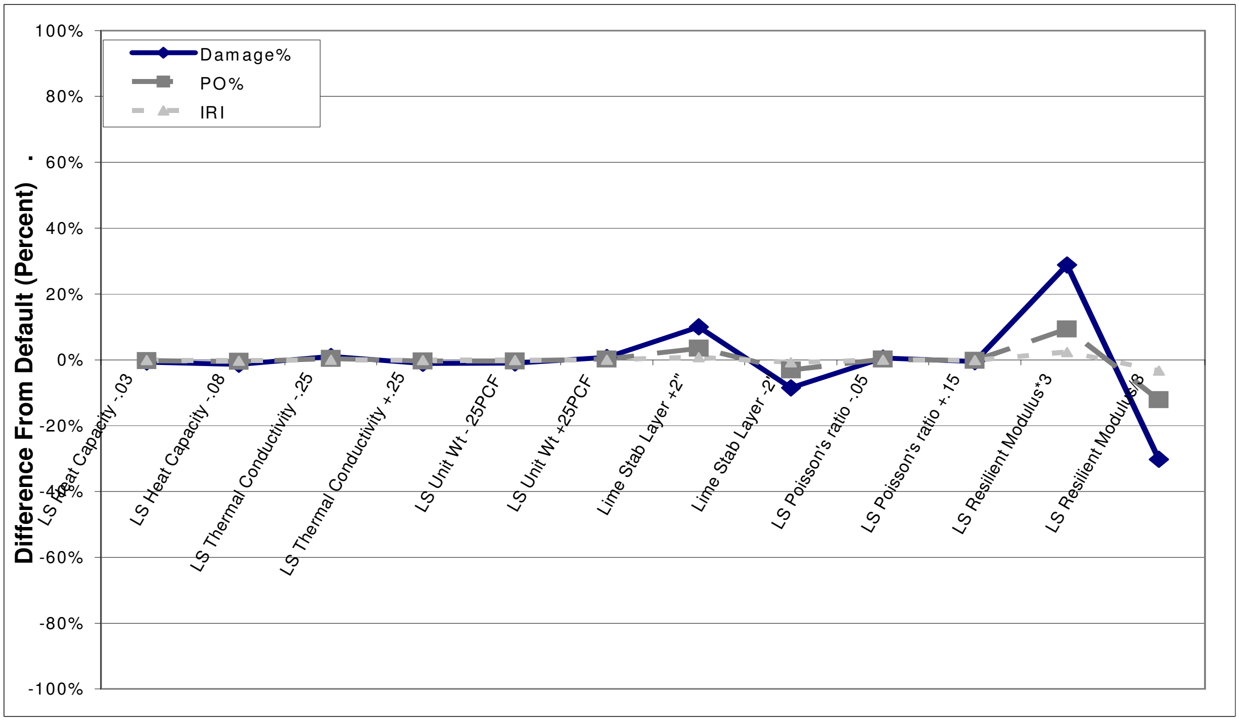

Figure J-12. Wet-Warm, CRCP, Lime Stabilized Variables.

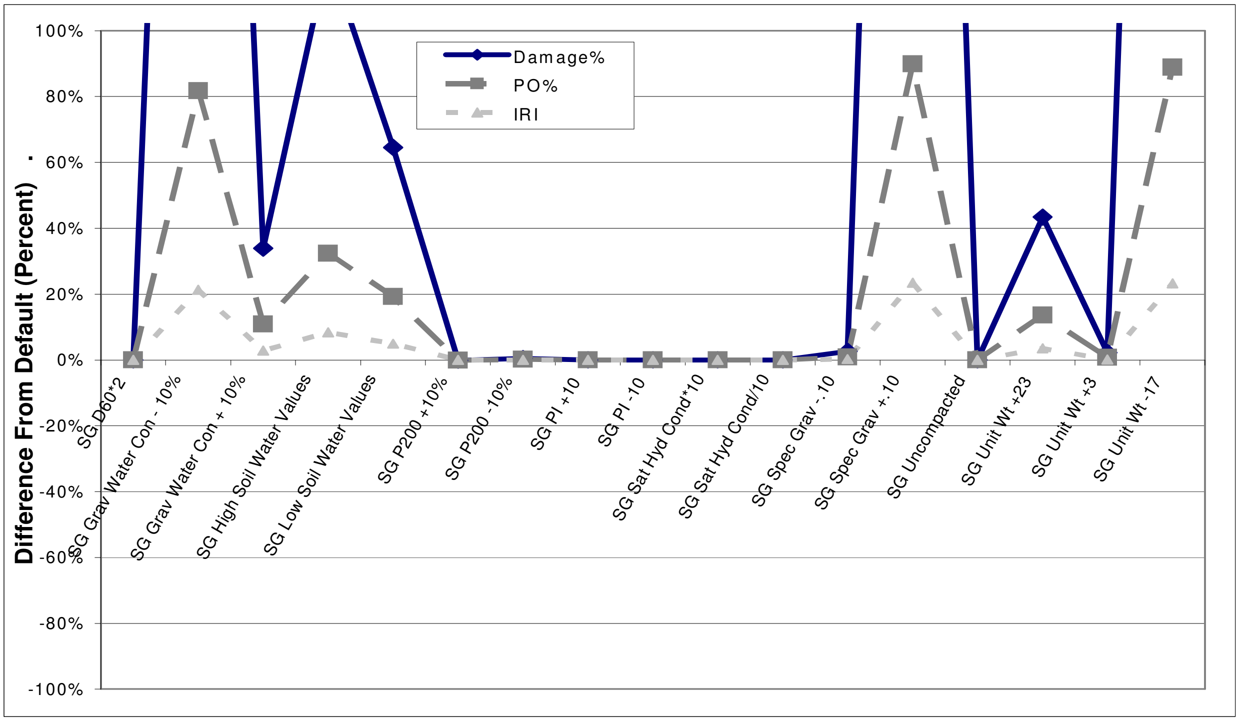

Figure J-13. Wet-Warm, CRCP, Subgrade ICM Variables.

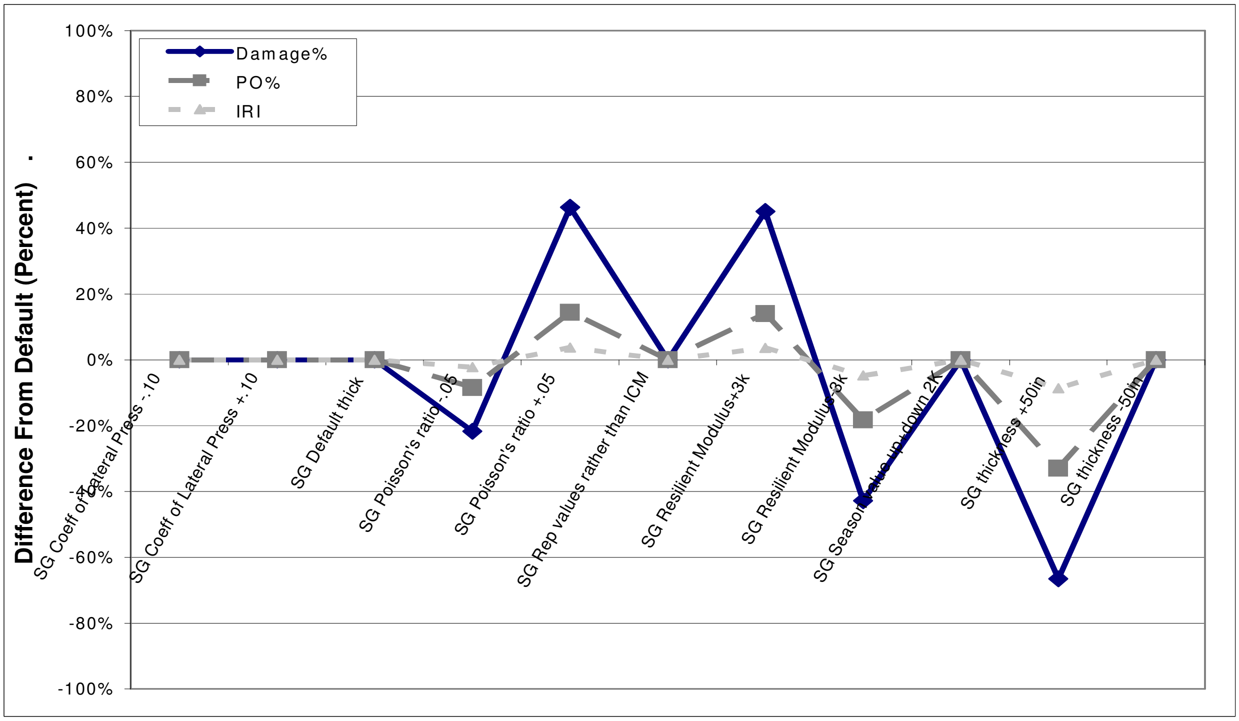

Figure J-14. Wet-Warm, CRCP, Subgrade Strength Variables.

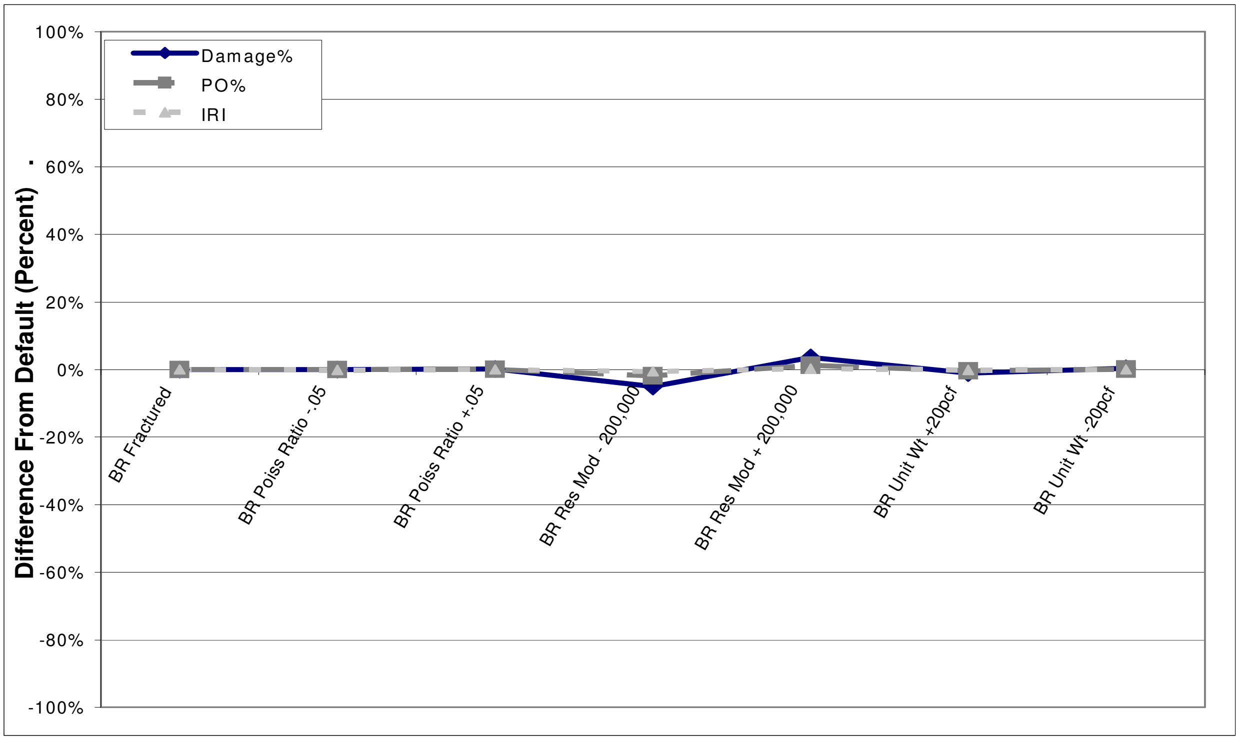

Figure J-15. Wet-Warm, CRCP, Bedrock Variables.

Table J-7. Results of Wet-Warm, CRCP, General Variables.

Description	Category	Damage%	PO%	IRI
Construction −5 month (Cold)	01-General	<	<	<
Construction +2 month (Hot)	01-General	<	=	<
Construction +4 month	01-General	>	>	=
Traffic + 4 month (More Cure)	01-General	<	<	<
Traffic −1 month (Less Cure)	01-General	>	>	=
Local Road TTC Class 9	02-Site	=	=	=
Minor Arterial TTC Class 4	02-Site	=	=	=

Table J-8. Results of Wet-Warm, CRCP, Traffic Variables.

Description	Category	Damage%	PO%	IRI
AADT −1600 (20%)	03-Traffic	< <	< <	< <
AADT +1600 (20%)	03-Traffic	> >	> >	> >
Lane Width 2' Less	03-Traffic-General	=	=	=
Lane Width 2' More	03-Traffic-General	=	=	=
Wander 2" Less	03-Traffic-General	< <	< <	< <
Wander 2" More	03-Traffic-General	> >	> >	> >
Wheel Loca 4" Close Lane Mark	03-Traffic-General	> > >	> > >	> > >
Wheel Loca 4" Far Lane Mark	03-Traffic-General	< < <	< < <	< < <
All Tire Press +30 psi	03-Traffic-General-Axle	=	=	=
All Tire Press −30 psi	03-Traffic-General-Axle	=	=	=
Dual Tire Press +30 psi	03-Traffic-General-Axle	=	=	=
Dual Tire Press −30 psi	03-Traffic-General-Axle	=	=	=
Single Tire Press +30 psi	03-Traffic-General-Axle	=	=	=
Single Tire Press −30 psi	03-Traffic-General-Axle	=	=	=

Table J-9. Results of Wet-Warm, CRCP, Climate Variables.

Description	Category	Damage%	PO%	IRI
Elevation −18'	04-Climate	=	=	=
Elevation +30'	04-Climate	=	=	=
Latitude −0.9	04-Climate	<<	<<	<<
Latitude +0.6	04-Climate	>	>	>
Longitude −0.8	04-Climate	<	<	<
Longitude +0.7	04-Climate	<<	<<	<<
Water Table Depth at 1'	04-Climate	<<	<<	<<
Water Table Depth at 50'	04-Climate	>>	>>	>>

Table J-10. Results of Wet-Warm, CRCP, DesignVariables.

Description	Category	Damage%	PO%	IRI
AC Shoulder	06-Design	=	=	=
Bar Diameter −0.125"	06-Design	=	=	=
Bar Diameter +0.125"	06-Design	=	=	=
Base/Slab Friction Coeff −3.4	06-Design	>>>	>>>	>>>
Base/Slab Friction Coeff +2.9	06-Design	=	=	=
* Curl/Warp Temp Diff +4	06-Design	<<<	<<<	<<<
* Curl/Warp Temp Diff −5	06-Design	>>>	>>>	>>>
* Decrease Erodibility	06-Design	>	>	=
* Increase Erodibility	06-Design	<	=	<
Mean Crack Spacing −18"	06-Design	=	=	=
Mean Crack Spacing - Default	06-Design	=	=	=
Mean Crack Spacing +24"	06-Design	=	=	=
Steel % −0.2%	06-Design	>>>	>>>	>>>
Steel % +0.2%	06-Design	=	=	=
Steel at 1/4 Depth	06-Design	=	=	=

* - Trend seems inconsistent with engineering principles.

Table J-11. Results of Wet-Warm, CRCP, Drainage Variables.

Description	Category	Damage%	PO%	IRI
Cross Slope +2%	07-Drain	=	=	=
Cross Slope −2%	07-Drain	=	=	=
Drainage Path Length +3'	07-Drain	=	=	=
Drainage Path Length −2'	07-Drain	=	=	=
Infiltration-Extreme	07-Drain	=	=	=
Infiltration-Negligible	07-Drain	>	>	=
Surf Shortwave Absorp −0.05	07-Drain	< <	< <	< <
Surf Shortwave Absorp +0.05	07-Drain	> >	> >	> >

Table J-12. Results of Wet-Warm, CRCP, Mix Variables.

Description	Category	Damage%	PO%	IRI
Basalt Aggregate	08-CRC-Mix	=	=	=
Cement Content +47 lb/yd^3	08-CRC-Mix	=	=	=
Cement Content −47 lb/yd^3	08-CRC-Mix	=	=	=
Chert Aggregate	08-CRC-Mix	=	=	=
Days to Develop 50% +15	08-CRC-Mix	=	=	=
Days to Develop 50% −15	08-CRC-Mix	=	=	=
Granite Aggregate	08-CRC-Mix	=	=	=
Revers Shrink +25%	08-CRC-Mix	>	=	=
Revers Shrink −25%	08-CRC-Mix	<	<	<
Water/Cement Ratio −0.03	08-CRC-Mix	=	=	=
Water/Cement Ratio +0.03	08-CRC-Mix	=	=	=
Wet Cure	08-CRC-Mix	=	=	=
Zero Stress Temp +23 °F	08-CRC-Mix	> > >	> > >	> > >
Zero Stress Temp 107 °F	08-CRC-Mix	=	=	=
Zero Stress Temp −27 °F	08-CRC-Mix	=	=	=

Table J-13. Results of Wet-Warm, CRCP, Strength Variables.

Description	Category	Damage%	PO%	IRI
20Yr/28Day Ratio −0.15	08-CRC-Strength	> >	> >	> >
20Yr/28Day Ratio +0.15	08-CRC-Strength	< <	< < <	< < <
E +1000 ksi	08-CRC-Strength	> > >	> > >	> > >
E =4000, Default	08-CRC-Strength	=	=	=
E −800 ksi	08-CRC-Strength	=	=	=
Level 1 CRC Strength Data-High	08-CRC-Strength	> > >	> > >	> > >
Level 1 CRC Strength Data-Low	08-CRC-Strength	< < <	< < <	< < <
Level 1 CRC Strength Data-Mid	08-CRC-Strength	< < <	< < <	< < <
Level 2 Def Compress Strngth	08-CRC-Strength	< <	< <	< <
Level 2 Hig Compress Strngth	08-CRC-Strength	< < <	< < <	< < <
Level 2 Min Compress Strngth	08-CRC-Strength	> > >	> > >	> > >
Level 3 Mr −40 psi	08-CRC-Strength	> > >	> > >	> > >
Level 3 Mr +50 psi	08-CRC-Strength	< < <	< < <	< < <

Table J-14. Results of Wet-Warm, CRCP, Thermal Variables.

Description	Category	Damage%	PO%	IRI
Coefficient of Contraction +3	08-CRC-Thermal	> > >	> > >	> > >
Coefficient of Contraction −2	08-CRC-Thermal	< < <	< < <	< < <
CRC Thickness +2"	08-CRC-Thermal	< < <	< < <	< < <
CRC Thickness −2"	08-CRC-Thermal	> > >	> > >	> > >
Heat Capacity −0.03	08-CRC-Thermal	>	>	>
Heat Capacity +0.02	08-CRC-Thermal	<	<	<
Poisson's Ratio −0.05	08-CRC-Thermal	< < <	< < <	< < <
Poisson's Ratio +0.05	08-CRC-Thermal	> >	> >	> >
Thermal Conductivity −0.10	08-CRC-Thermal	> >	> >	> >
Thermal Conductivity +0.20	08-CRC-Thermal	< <	< <	< <
Ultimate Shrink +157 psi	08-CRC-Thermal	>	>	=
Ultimate Shrink −143 psi	08-CRC-Thermal	<	<	<
Unit Wt +5 pcf	08-CRC-Thermal	< <	< < <	< < <
Unit Wt −5 pcf	08-CRC-Thermal	> >	> >	> >

Table J-15. Results of Wet-Warm, CRCP, AC Binder Variables.

Description	Category	Damage%	PO%	IRI
AC PG Grade 64-16	09-AC-Binder	>	>	=
AC PG Grade 76-28	09-AC-Binder	=	=	<
AC Visc Grade 10	09-AC-Binder	>	>	=
AC Visc Grade 20	09-AC-Binder	>	>	=
AC Visc Grade 30	09-AC-Binder	=	=	=

Table J-16. Results of Wet-Warm, CRCP, AC General Variables.

Description	Category	Damage%	PO%	IRI
AC Air Voids +2.5%	09-AC-General	>	>	=
AC Air Voids −2%	09-AC-General	<	<	<
AC Effective Binder Content +3%	09-AC-General	>	>	=
AC Effective Binder Content −3%	09-AC-General	<	<	<
AC Heat Capacity +0.08	09-AC-General	>	>	>
AC Heat Capacity +0.17	09-AC-General	>	>	>
AC Poisson’s Ratio −0.05	09-AC-General	<	=	<
AC Poisson’s Ratio +0.05	09-AC-General	>	=	=
AC Reference Temp +5 °F	09-AC-General	=	=	<
AC Reference Temp −5 °F	09-AC-General	=	=	=
AC Thermal Conductivity −0.14	09-AC-General	<	<	<
AC Thermal Conductivity +0.14	09-AC-General	>	>	=
AC Unit Wt +6 pcf	09-AC-General	>	=	=
AC Unit Wt −6 pcf	09-AC-General	<	=	<

Table J-17. Results of Wet-Warm, CRCP, AC Mix Variables.

Description	Category	Damage%	PO%	IRI
AC % Pass #200 −2%	09-AC-Mix	>	=	=
AC % Pass #200 +2%	09-AC-Mix	=	=	<
AC % Retained #4 +10%	09-AC-Mix	>	>	=
AC % Retained #4 −10%	09-AC-Mix	<	=	<
AC % Retained 3/4" +10%	09-AC-Mix	<	=	<
AC % Retained 3/4" −10%	09-AC-Mix	>	>	=
AC % Retained 3/8" +10%	09-AC-Mix	<	=	<
AC % Retained 3/8" −10%	09-AC-Mix	>	=	=
AC Layer +1"	09-AC-Mix	>>	>>	>>

Table J-18. Results of Wet-Warm, CRCP, Cement Stabilized ICM Variables.

Description	Category	Damage%	PO%	IRI
CS Heat Capacity −0.03	10-CS-ICM	<	<	<
CS Heat Capacity −0.08	10-CS-ICM	<	<	<
CS Thermal Conductivity −0.25	10-CS-ICM	<	<	<
CS Thermal Conductivity +0.25	10-CS-ICM	>	>	=
CS Unit Wt −25 pcf	10-CS-ICM	<	<	<
CS Unit Wt +25 pcf	10-CS-ICM	>	>	=

Table J-19. Results of Wet-Warm, CRCP, Cement Stabilized Strength Variables.

Description	Category	Damage%	PO%	IRI
* Cement Stab Layer +1"	10-CS-Strength	> >	> >	> >
* Cement Stab Layer −1"	10-CS-Strength	< <	< <	< <
CS Poisson’s Ratio −0.05	10-CS-Strength	<	<	<
CS Poisson’s Ratio +0.05	10-CS-Strength	>	>	>
CS Resilient Modulus×2	10-CS-Strength	> >	> >	> >
CS Resilient Modulus/2	10-CS-Strength	< <	< <	< <

* - Trend seems inconsistent with engineering principles.

Table J-20. Results of Wet-Warm, CRCP, Lime Stabilized ICM Variables.

Description	Category	Damage%	PO%	IRI
LS Heat Capacity −0.03	11-LS-ICM	<	<	<
LS Heat Capacity −0.08	11-LS-ICM	<	<	<
LS Thermal Conductivity −0.25	11-LS-ICM	>	>	=
LS Thermal Conductivity +0.25	11-LS-ICM	<	<	<
LS Unit Wt −25 pcf	11-LS-ICM	<	<	<
LS Unit Wt +25 pcf	11-LS-ICM	>	>	=

Table J-21. Results of Wet-Warm, CRCP, Lime Stabilized Strength Variables.

Description	Category	Damage%	PO%	IRI
* Lime Stab Layer +2"	11-LS-Strength	> >	> >	> >
* Lime Stab Layer −2"	11-LS-Strength	< <	< <	< <
LS Poisson’s Ratio −0.05	11-LS-Strength	>	>	=
LS Poisson’s Ratio +0.15	11-LS-Strength	<	<	<
LS Resilient Modulus×3	11-LS-Strength	> >	> >	> >
LS Resilient Modulus/3	11-LS-Strength	< <	< <	< <

* - Trend seems inconsistent with engineering principles.

Table J-22. Results of Wet-Warm, CRCP, Subgrade ICM Variables.

Description	Category	Damage%	PO%	IRI
SG D60×2	12-SG-ICM	=	=	=
SG Grav Water Con −10%	12-SG-ICM	> > >	> > >	> > >
SG Grav Water Con +10%	12-SG-ICM	> >	> >	> >
SG High Soil Water Values	12-SG-ICM	> > >	> > >	> > >
SG Low Soil Water Values	12-SG-ICM	> > >	> > >	> > >
SG P200 +10%	12-SG-ICM	<	=	=
SG P200 −10%	12-SG-ICM	>	>	=
SG PI +10	12-SG-ICM	=	=	=
SG PI −10	12-SG-ICM	=	=	=
SG Sat Hyd Cond×10	12-SG-ICM	=	=	=
SG Sat Hyd Cond/10	12-SG-ICM	=	=	=
SG Spec Grav −0.10	12-SG-ICM	>	>	>
SG Spec Grav +0.10	12-SG-ICM	> > >	> > >	> > >
SG Uncompacted	12-SG-ICM	=	=	=
SG Unit Wt +23 pcf	12-SG-ICM	> > >	> >	> >
SG Unit Wt +3 pcf	12-SG-ICM	>	>	>
SG Unit Wt −17 pcf	12-SG-ICM	> > >	> > >	> > >

Table J-23. Results of Wet-Warm, CRCP, Subgrade Strength Variables.

Description	Category	Damage%	PO%	IRI
SG Coeff of Lateral Press −0.10	12-SG-Strength	=	=	=
SG Coeff of Lateral Press +0.10	12-SG-Strength	=	=	=
SG Default Thick	12-SG-Strength	=	=	=
SG Poisson’s Ratio −0.05	12-SG-Strength	< <	< <	< <
SG Poisson’s Ratio +0.05	12-SG-Strength	> > >	> >	> >
SG Rep Values Rather than ICM	12-SG-Strength	=	=	=
* SG Resilient Modulus +3 ksi	12-SG-Strength	> > >	> >	> >
* SG Resilient Modulus −3 ksi	12-SG-Strength	< < <	< < <	< < <
SG Season Value Up+Down 2 ksi	12-SG-Strength	=	=	=
SG Thickness +50"	12-SG-Strength	< < <	< < <	< < <
SG Thickness −50"	12-SG-Strength	=	=	=

* - Trend seems inconsistent with engineering principles.

Table J-24. Results of Wet-Warm, CRCP, Bedrock Variables.

Description	Category	Damage%	PO%	IRI
BR Fractured	13-BR	=	=	=
BR Poiss Ratio −0.05	13-BR	=	=	<
BR Poiss Ratio +0.05	13-BR	>	=	=
BR Res Mod −200,000 ksi	13-BR	<	<	<
BR Res Mod +200,000 ksi	13-BR	>	>	>
BR Unit Wt +20 pcf	13-BR	<	<	<
BR Unit Wt −20 pcf	13-BR	>	>	=

APPENDIX K

JPCP RESULTS

Table K-1. JPCP, Highly Significant Variables - Faulting Rank.

Description	Category	Faulting-Rank
Construction +4 Months	01-General	0.4
Construction -5 Months	01-General	0.1
Wheel Loca 4" Close to Lane	03-Traffic-General	0.3
Wheel Loca 4" Far to Lane	03-Traffic-General	0.2
AC Shoulder	05-JPC Design	0.3
Bar Diameter −0.125"	05-JPC Design	0.0
Bar Diameter +0.125"	05-JPC Design	0.1
Curl/Warp Temp Diff +4	05-JPC Design	0.2
Curl/Warp Temp Diff −5	05-JPC Design	0.1
Joint Spacing 12.5'	05-JPC Design	0.2
Joint Spacing 18'	05-JPC Design	0.2
No Dowels	05-JPC Design	0.0
Widened and Tied 14-90	05-JPC Design	0.1
Widened Slab 14'	05-JPC Design	0.1
Zero Stress Temp -21 °F	07-JPC-Mix	0.2
Thermal Mix Coeff of Contr ×4/6	07-JPC-Thermal	0.1
Thermal Mix Coeff of Contr ×9/6	07-JPC-Thermal	0.1
AC Layer −1" No AC	08-AC	0.3
Decrease Erodibility	05-JPC Design	0.4

Table K-2. JPCP, Significant Variables - Faulting Rank.

Description	Category	Faulting-Rank
Local Road TTC Class 9	02-Site	0.5
Minor Arterial TTC Class 4	02-Site	1.1
AADT −2318 (20%)	03-Traffic	1.0
AADT +2318 (20%)	03-Traffic	1.0
Wander 2" Less	03-Traffic-General	0.6
Wander 2" More	03-Traffic-General	0.8
Latitude −0.8	04-Climate	1.0
Longitude +1	04-Climate	1.0
Water Table Depth at 1'	04-Climate	2.2
Increase Erodibility	05-JPC Design	1.0
LTE −20%	05-JPC Design	1.5
LTE +20%	05-JPC Design	1.8
Widened and Tied 12-50	05-JPC Design	1.5
Surf Shortwave Absorp −0.05	06-JPC-Drain	1.8
Surf Shortwave Absorp +0.05	06-JPC-Drain	2.2
Cement Content +47 lb/yd^3	07-JPC-Mix	1.1
Cement Content −47 lb/yd^3	07-JPC-Mix	0.9
Cement Type II	07-JPC-Mix	0.9
Cement Type III	07-JPC-Mix	1.8
Ultimate Shrink +99	07-JPC-Mix	1.1
Ultimate Shrink −101	07-JPC-Mix	0.8
Water/Cement Ratio −0.03	07-JPC-Mix	2.2
Wet Cure	07-JPC-Mix	0.8
Zero Stress Temp +19 °F	07-JPC-Mix	0.5
E +1000 ksi	07-JPC-Strength	0.8
E −800 ksi	07-JPC-Strength	0.6
Lev 2 High Compress Strength	07-JPC-Strength	2.2
Lev 2 Min Compress Strength	07-JPC-Strength	1.0
Level 1 JPCP Strength-High	07-JPC-Strength	0.5
Level 1 JPCP Strength-Low	07-JPC-Strength	1.5
Level 1 JPCP Strength-Mid	07-JPC-Strength	1.0
JPCP −1"	07-JPC-Thermal	2.2
JPCP Poisson’s Ratio −0.05	07-JPC-Thermal	0.8
JPCP Poisson’s Ratio +0.05	07-JPC-Thermal	0.8
JPCP Unit Wt +5 pcf	07-JPC-Thermal	0.8
JPCP Unit Wt −5 pcf	07-JPC-Thermal	0.7
Thermal Conductivity +0.1	07-JPC-Thermal	1.3

Table K-2. JPCP, Significant Variables - Faulting Rank (Continued).

AC Top Layer +1"	08-AC	1.5
CHLS High Soil Water Values	09-CHLS-ICM	1.8
CHLS P200 +10%	09-CHLS-ICM	1.5
CH Lime Stab Layer −2"	09-CHLS-Str	2.2
SG Default Soil Water Values	10-SG-ICM	0.6
SG High Soil Water Values	10-SG-ICM	0.6
SG Low Soil Water Values	10-SG-ICM	0.7

Table K-3. JPCP, Highly Significant Variables - Slab Cracking Rank.

Description	Category	Slab Crk-Rank
Wheel Loca 4" Close to Lane	03-Traffic-General	0.4
AC Shoulder	05-JPC Design	0.1
Curl/Warp Temp Diff +4 °F	05-JPC Design	0.2
Curl/Warp Temp Diff −5 °F	05-JPC Design	0.1
Joint Spacing 12.5'	05-JPC Design	0.3
Joint Spacing 18'	05-JPC Design	0.1
Joint Spacing Random	05-JPC Design	0.1
LTE −20%	05-JPC Design	0.3
LTE +20%	05-JPC Design	0.5
Widened and Tied 12-50	05-JPC Design	0.3
Surf Shortwave Absorp +0.05	06-JPC-Drain	0.5
E +1000 ksi	07-JPC-Strength	0.1
E −800 ksi	07-JPC-Strength	0.2
Lev 2 Def Compress Strength	07-JPC-Strength	0.4
Lev 2 High Compress Strength	07-JPC-Strength	0.2
Lev 2 Min Compress Strength	07-JPC-Strength	0.2
Level 1 JPCP Strength-High	07-JPC-Strength	0.3
Level 1 JPCP Strength-Low	07-JPC-Strength	0.3
Level 1 JPCP Strength-Mid	07-JPC-Strength	0.3
Level 3 Mr −40 psi	07-JPC-Strength	0.1
Level 3 Mr +50 psi	07-JPC-Strength	0.3
JPCP +1"	07-JPC-Thermal	0.3
JPCP −1"	07-JPC-Thermal	0.1
JPCP Poisson's Ratio −0.05	07-JPC-Thermal	0.5
JPCP Poisson's Ratio +0.05	07-JPC-Thermal	0.3
Thermal Conductivity +0.1	07-JPC-Thermal	0.5

Table K-3. JPCP, Highly Significant Variables - Slab Cracking Rank.

Thermal Mix Coeff of Contr ×4/6	07-JPC-Thermal	0.2
Thermal Mix Coeff of Contr ×9/6	07-JPC-Thermal	0.1
AC Layer −1" No AC	08-AC	0.3
SG Default Soil Water Values	10-SG-ICM	0.4
SG High Soil Water Values	10-SG-ICM	0.4
SG Low Soil Water Values	10-SG-ICM	0.4

Table K-4. JPCP, Significant Variables - Slab Cracking Rank.

Description	Category	Slab Crk-Rank
Local Road TTC Class 9	02-Site	0.7
Minor Arterial TTC Class 4	02-Site	1.2
AADT −2318 (20%)	03-Traffic	1.1
AADT +2318 (20%)	03-Traffic	0.9
Wander 2" Less	03-Traffic-General	1.2
Wander 2" More	03-Traffic-General	1.5
Wheel Loca 4" Far to Lane	03-Traffic-General	0.5
Latitude −0.8	04-Climate	1.5
Longitude +1	04-Climate	1.1
Longitude −1	04-Climate	1.1
Widened and Tied 14-90	05-JPC Design	2.4
Widened Slab 14'	05-JPC Design	2.4
Surf Shortwave Absorp −0.05	06-JPC-Drain	0.6
Heat Capacity +0.03	07-JPC-Thermal	1.7
JPCP Unit Wt +5 pcf	07-JPC-Thermal	1.2
JPCP Unit Wt −5 pcf	07-JPC-Thermal	1.5
Thermal Conductivity −0.1	07-JPC-Thermal	0.6
AC Heat Capacity +0.17	08-AC-General	1.7
SG Unit Wt −16.7 pcf	10-SG-ICM	2.1
SG Thickness −25"	10-SG-Str	2.0

Table K-5. JPCP, Highly Significant Variables - IRI Rank.

Description	Category	IRI-Rank
Construction −5 Months	01-General	0.3
Wheel Loca 4" Close to Lane	03-Traffic-General	0.3
Wheel Loca 4" Far to Lane	03-Traffic-General	0.3
AC Shoulder	05-JPC Design	0.1
Bar Diameter −0.125"	05-JPC Design	0.1
Bar Diameter +0.125"	05-JPC Design	0.3
Curl/Warp Temp Diff −5 °F	05-JPC Design	0.1
Joint Spacing 12.5'	05-JPC Design	0.3
Joint Spacing 18'	05-JPC Design	0.2
Joint Spacing Random	05-JPC Design	0.2
LTE −20%	05-JPC Design	0.4
No Dowels	05-JPC Design	0.0
Widened and Tied 12-50	05-JPC Design	0.4
Widened and Tied 14-90	05-JPC Design	0.1
Widened Slab 14'	05-JPC Design	0.1
E +1000 ksi	07-JPC-Strength	0.2
E −800 ksi	07-JPC-Strength	0.3
Lev 2 Min Compress Strength	07-JPC-Strength	0.4
Level 1 JPCP Strength-Low	07-JPC-Strength	0.4
Level 3 Mr −40 psi	07-JPC-Strength	0.2
Level 3 Mr +50 psi	07-JPC-Strength	0.5
JPCP −1"	07-JPC-Thermal	0.2
JPCP Poisson's Ratio +0.05	07-JPC-Thermal	0.4
Thermal Mix Coeff of Contr ×4/6	07-JPC-Thermal	0.1
Thermal Mix Coeff of Contr ×9/6	07-JPC-Thermal	0.1
AC Layer −1" No AC	08-AC	0.3
SG High Soil Water Values	10-SG-ICM	0.5

Table K-6. JPCP, Significant Variables - IRI Rank.

Description	Category	IRI-Rank
Construction +4 Months	01-General	0.8
Initial IRI +12	02-Analysis	0.8
Initial IRI −13	02-Analysis	0.8
Local Road TTC Class 9	02-Site	0.6
Minor Arterial TTC Class 4	02-Site	1.2
AADT −2318 (20%)	03-Traffic	1.1
AADT +2318 (20%)	03-Traffic	0.9
Wander 2" Less	03-Traffic-General	0.8
Wander 2" More	03-Traffic-General	1.0
Latitude −0.8	04-Climate	1.2
Longitude +1	04-Climate	1.0
Longitude −1	04-Climate	2.3
Decrease Erodibility	05-JPC Design	0.9
Increase Erodibility	05-JPC Design	2.0
LTE + 20%	05-JPC Design	0.7
Surf Shortwave Absorp −0.05	06-JPC-Drain	0.9
Surf Shortwave Absorp +0.05	06-JPC-Drain	0.7
Cement Content +47 lb/yd^3	07-JPC-Mix	2.2
Cement Content −47 lb/yd^3	07-JPC-Mix	1.9
Cement Type II	07-JPC-Mix	2.0
Ultimate Shrink +99	07-JPC-Mix	2.3
Ultimate Shrink −101	07-JPC-Mix	1.8
Wet Cure	07-JPC-Mix	1.8
Zero Stress Temp +19 °F	07-JPC-Mix	1.0
Zero Stress Temp −21 °F	07-JPC-Mix	0.5
Lev 2 Def Compress Strength	07-JPC-Strength	0.8
Lev 2 High Compress Strength	07-JPC-Strength	0.5
Level 1 JPCP Strength-High	07-JPC-Strength	0.9
Level 1 JPCP Strength-Mid	07-JPC-Strength	0.8
JPCP +1"	07-JPC-Thermal	0.7
JPCP Poisson's Ratio −0.05	07-JPC-Thermal	0.6
Thermal Conductivity −0.1	07-JPC-Thermal	0.9
Thermal Conductivity +0.1	07-JPC-Thermal	0.7
AC Top Layer +1"	08-AC	2.3
AC Heat Capacity +0.17	08-AC-General	2.4
SG Default Soil Water Values	10-SG-ICM	0.5
SG Low Soil Water Values	10-SG-ICM	0.5
SG Unit Wt −16.7 pcf	10-SG-ICM	2.5
SG Thickness −25"	10-SG-Str	2.4

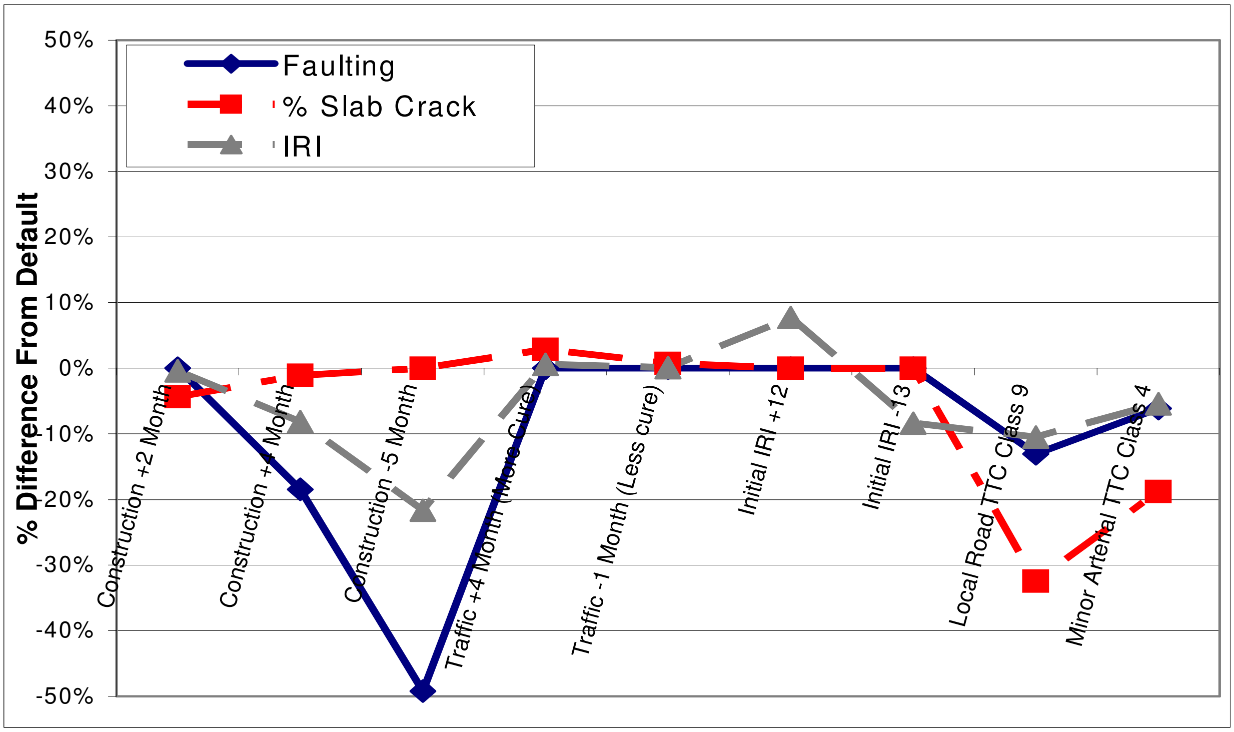

Figure K-1. JPCP, General Variables.

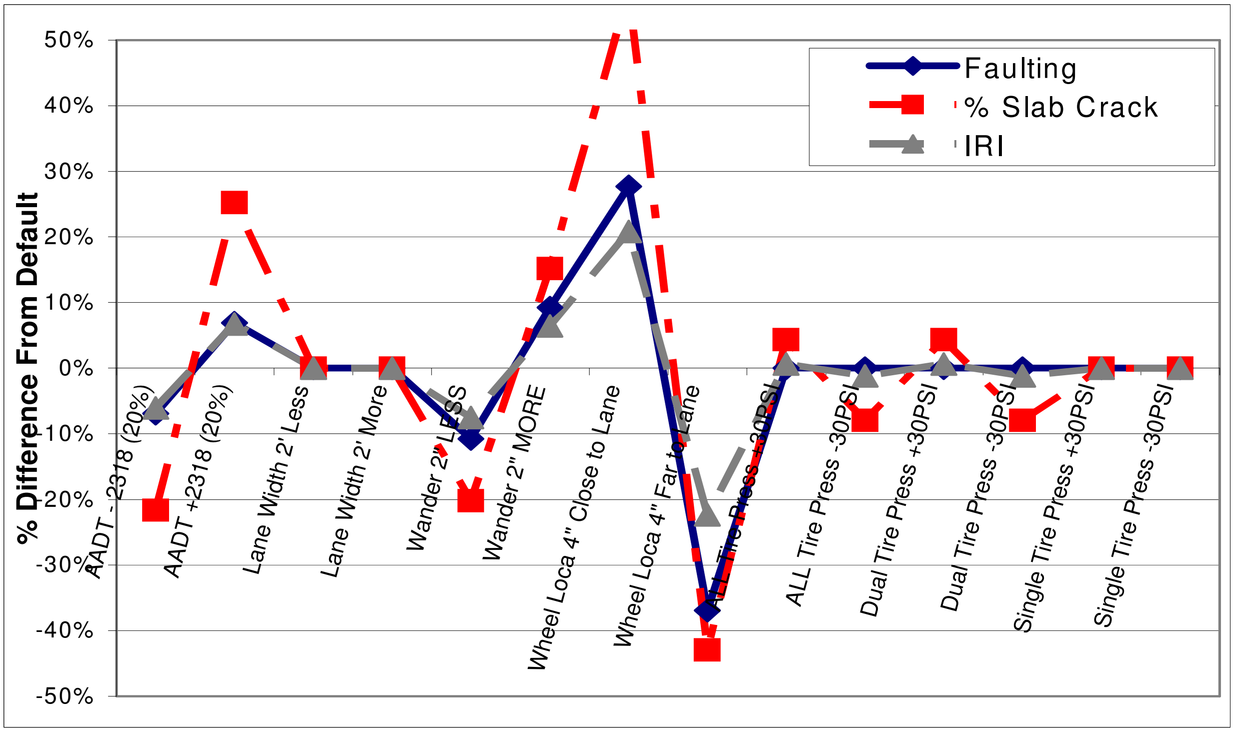

Figure K-2. JPCP, Traffic Variables.

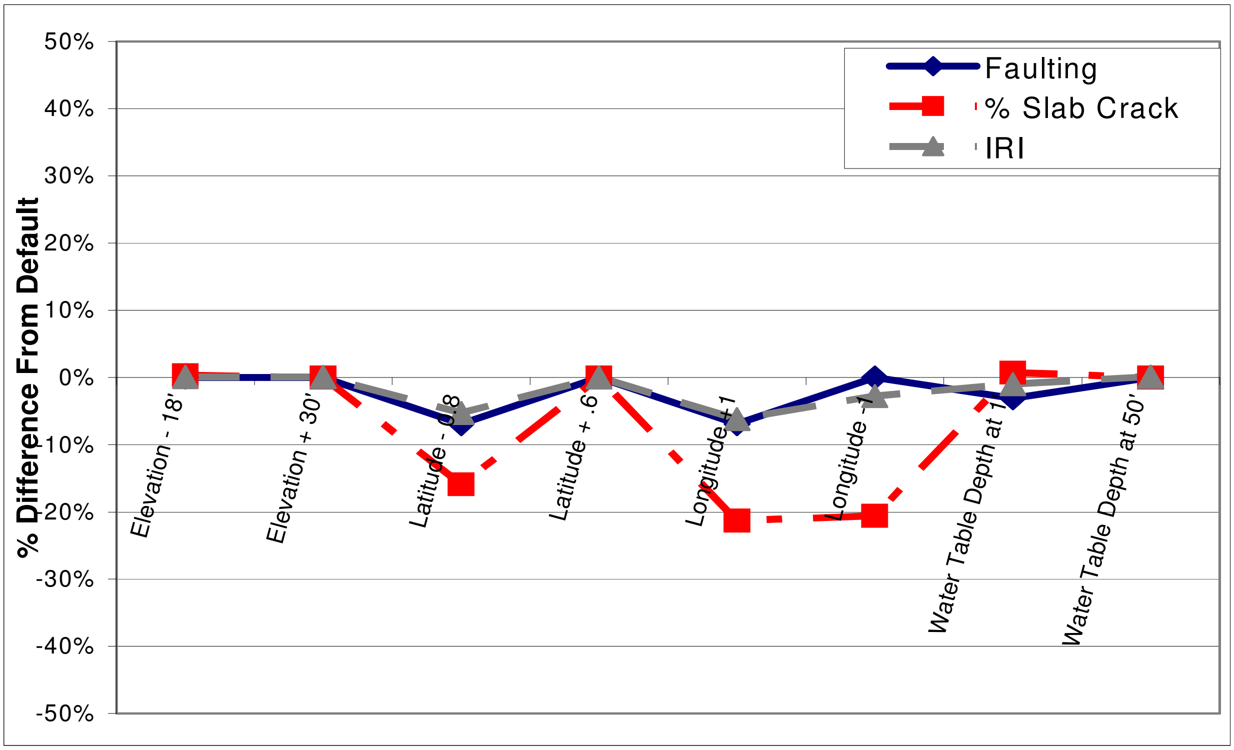

Figure K-3. JPCP, Climate Variables.

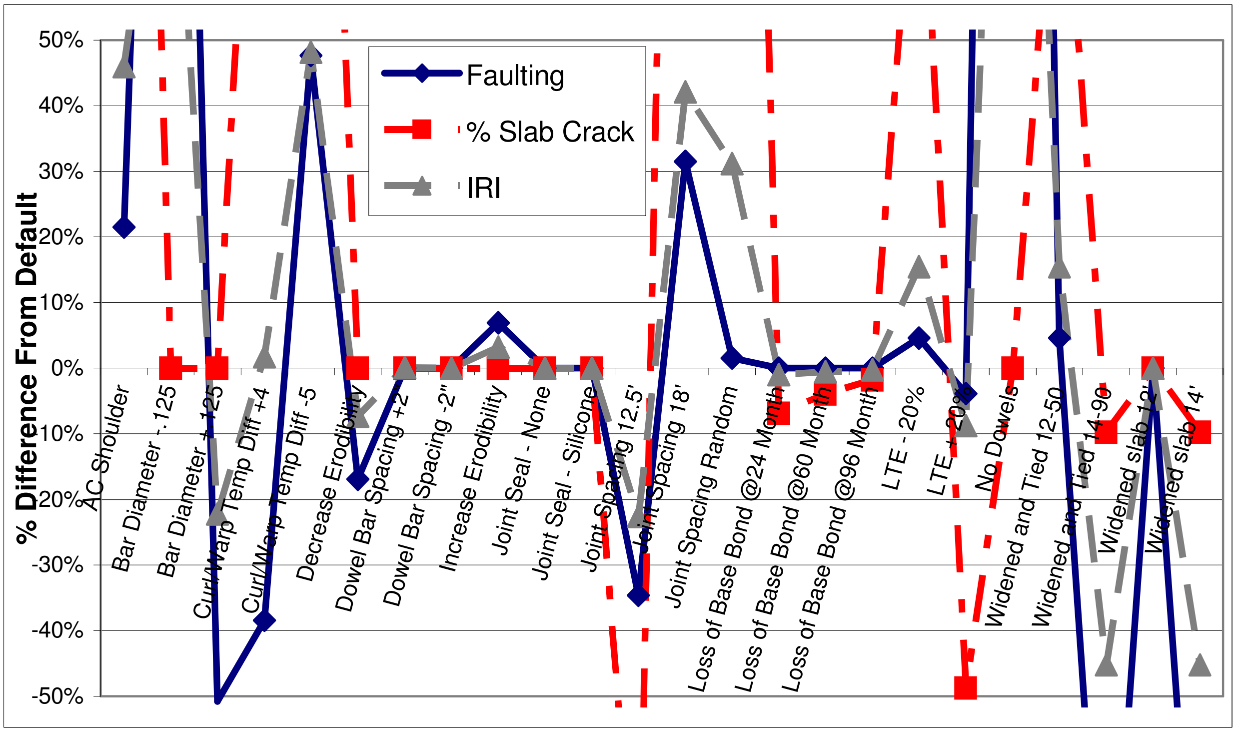

Figure K-4. JPCP, Design Variables.

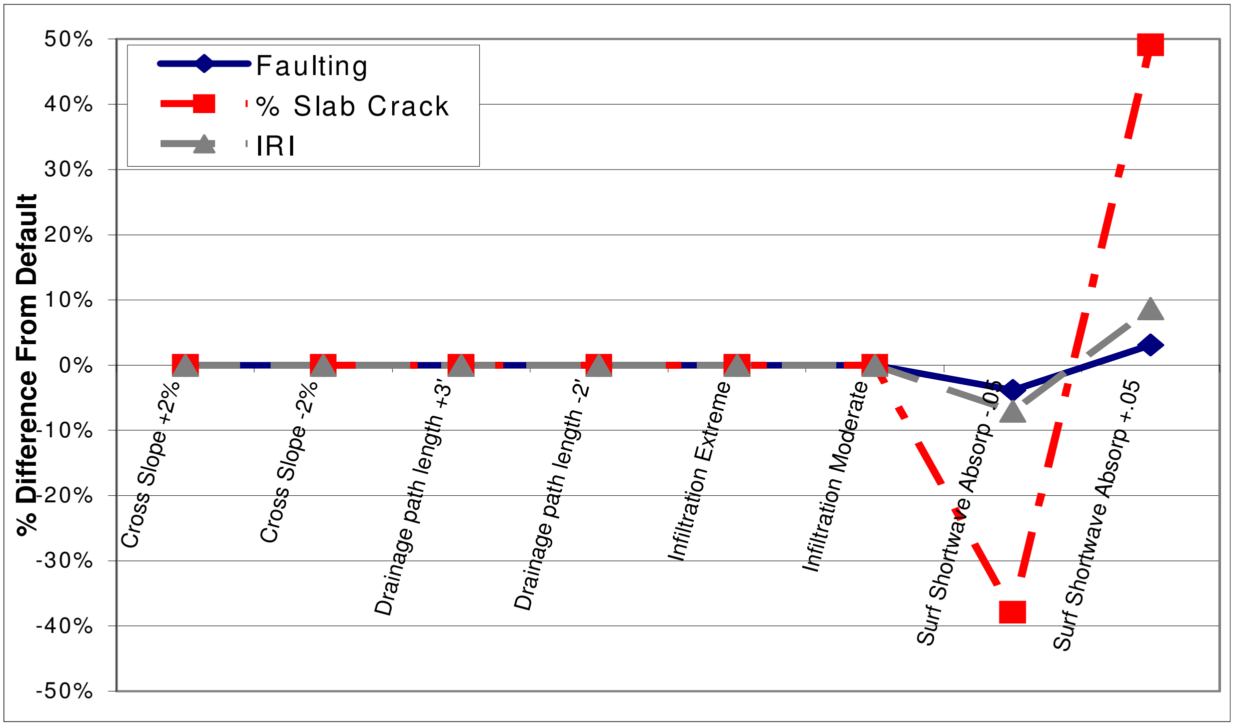

Figure K-5. JPCP, Drainage Variables.

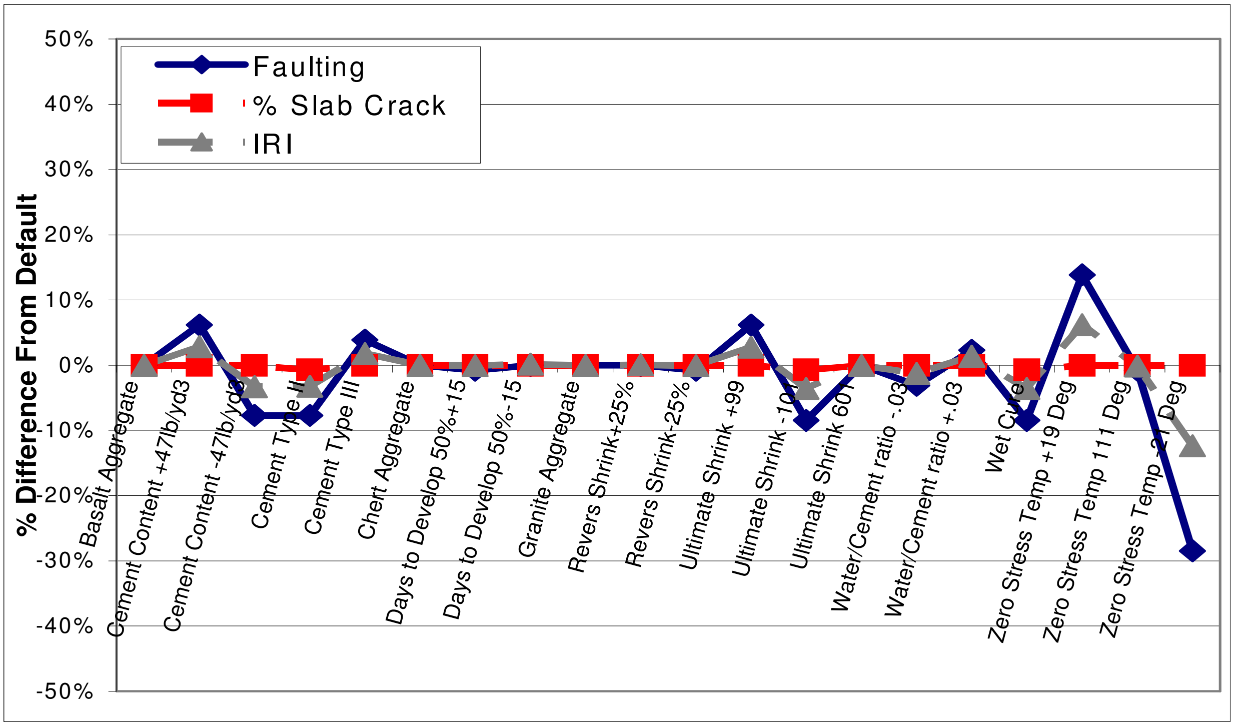

Figure K-6. JPCP, JPCP Mix Variables.

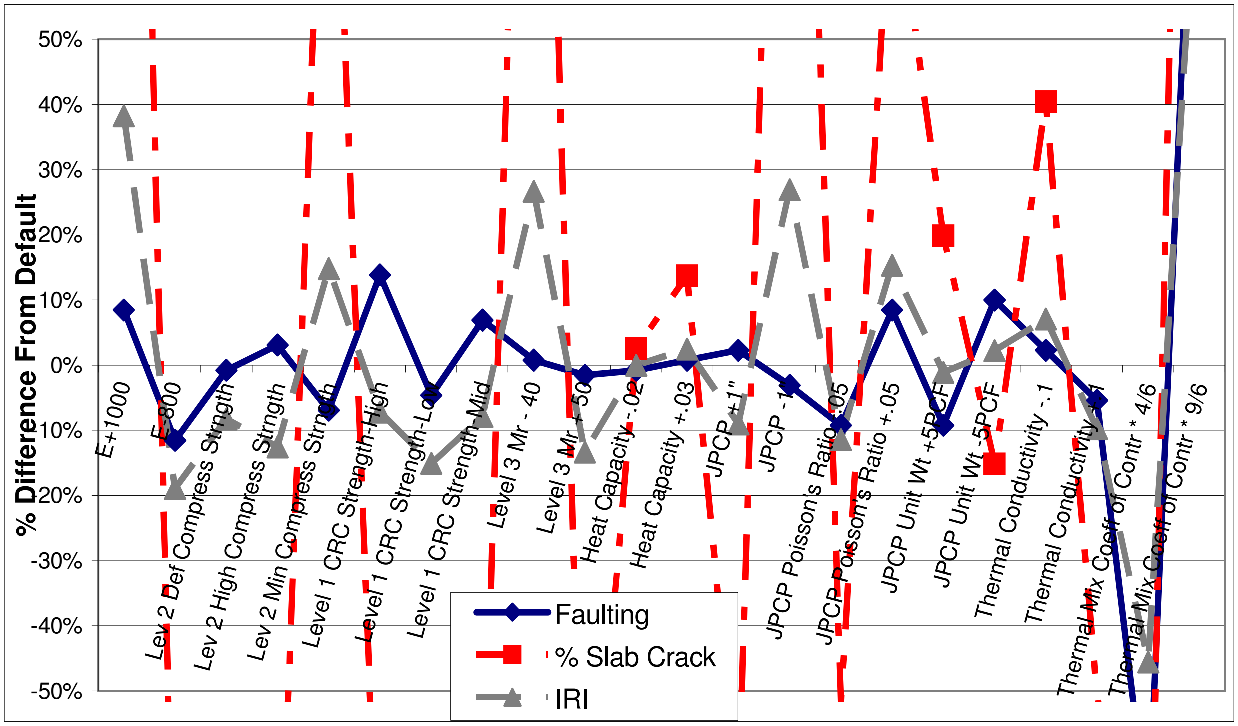

Figure K-7. JPCP, JPCP Strength Variables.

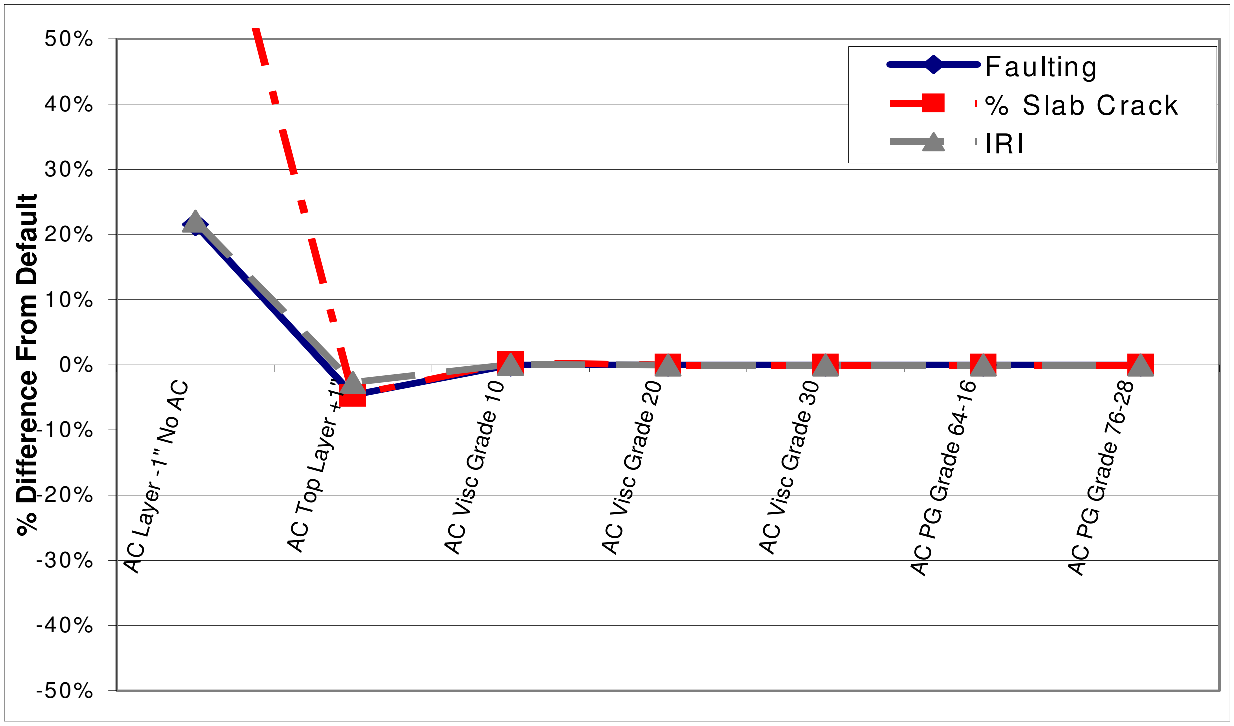

Figure K-8. JPCP, AC Binder Variables.

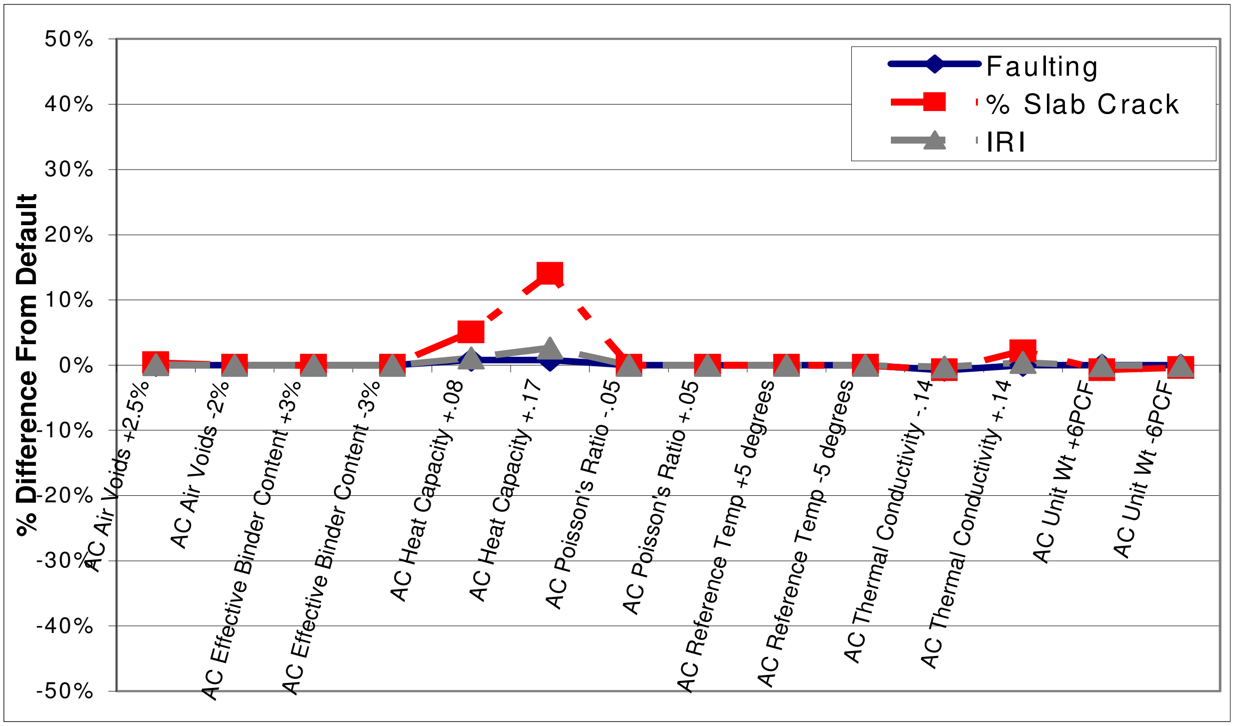

Figure K-9. JPCP, AC General Variables.

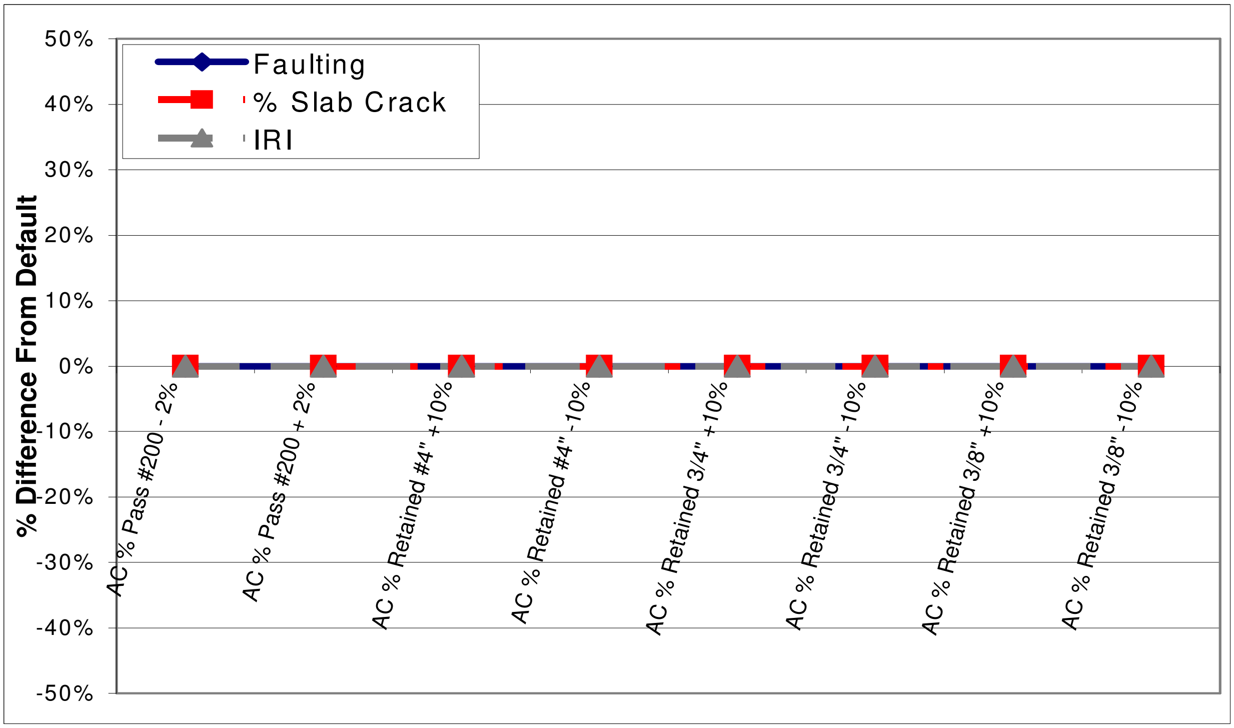

Figure K-10. JPCP, AC Mix Variables.

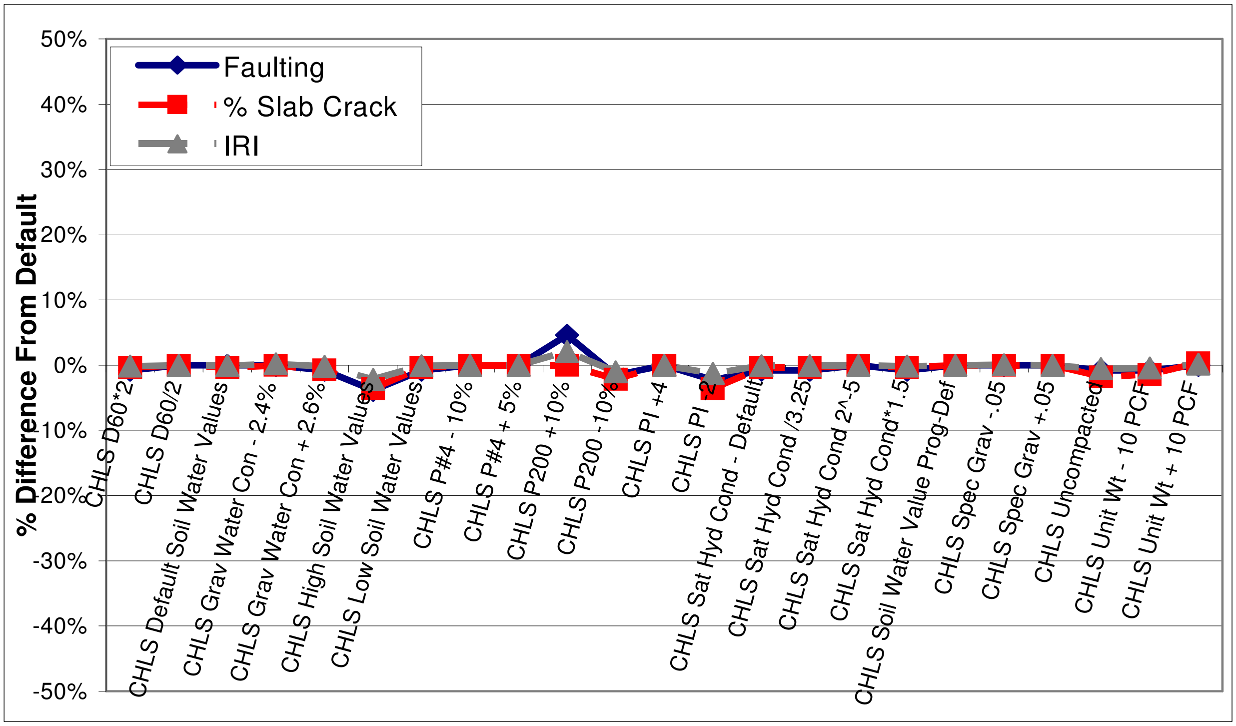

Figure K-11. JPCP, Lime Modified ICM Variables.

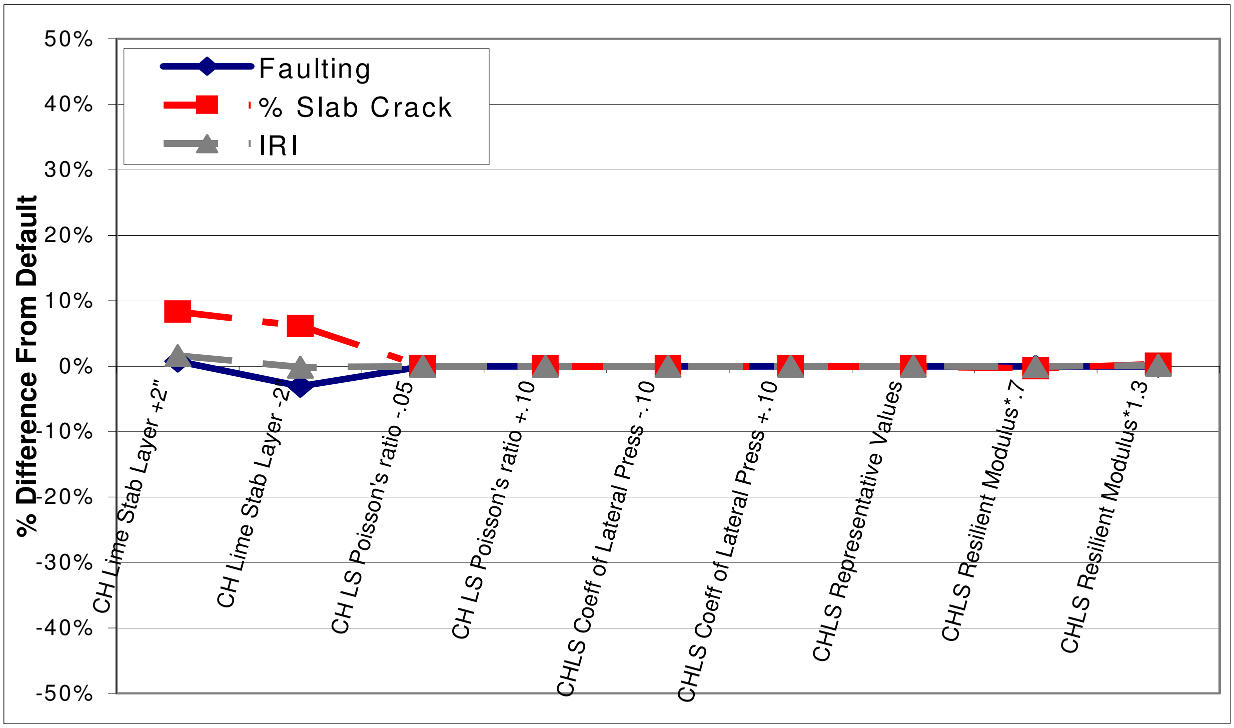

Figure K-12. JPCP, Lime Modified Strength Variables.

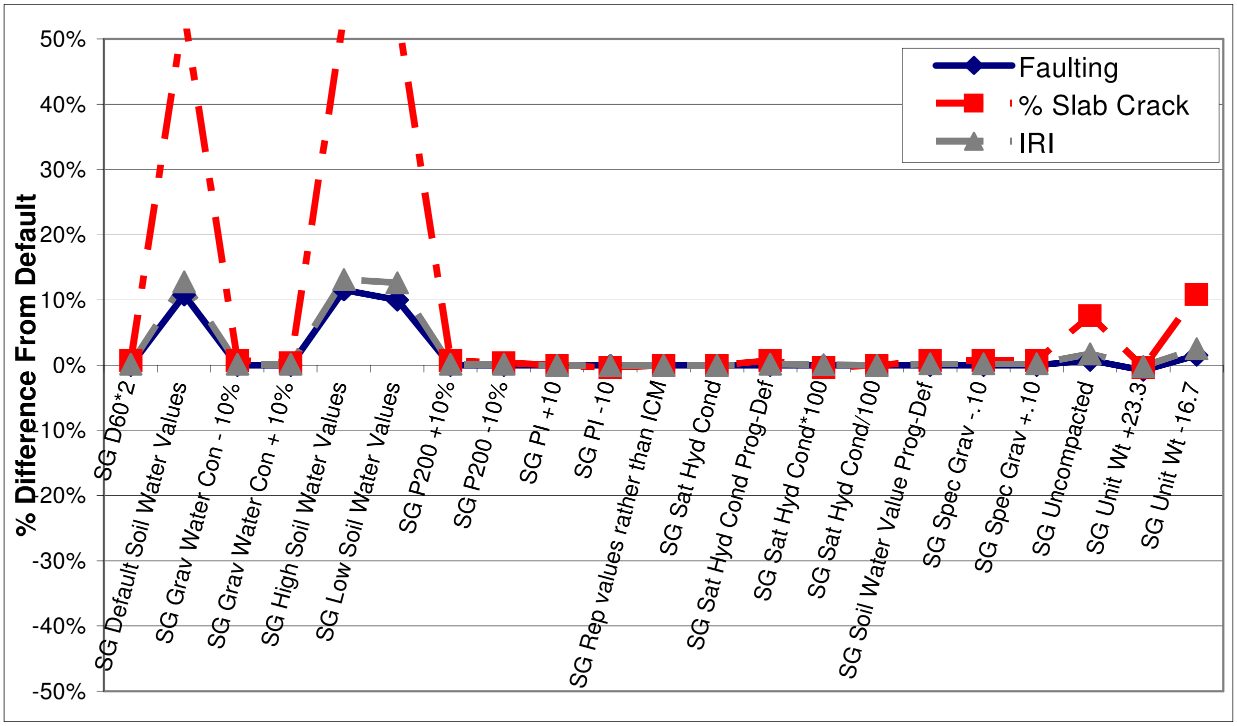

Figure K-13. JPCP, Subgrade ICM Variables.

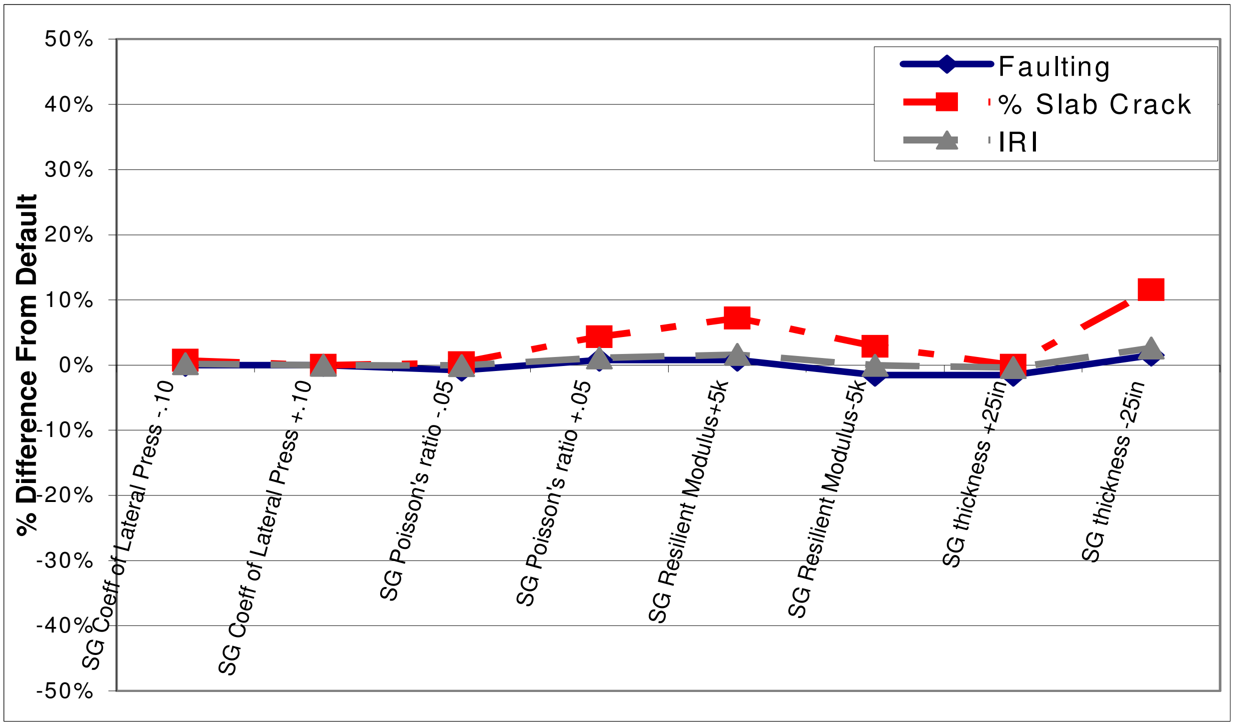

Figure K-14. JPCP, Subgrade Strength Variables.

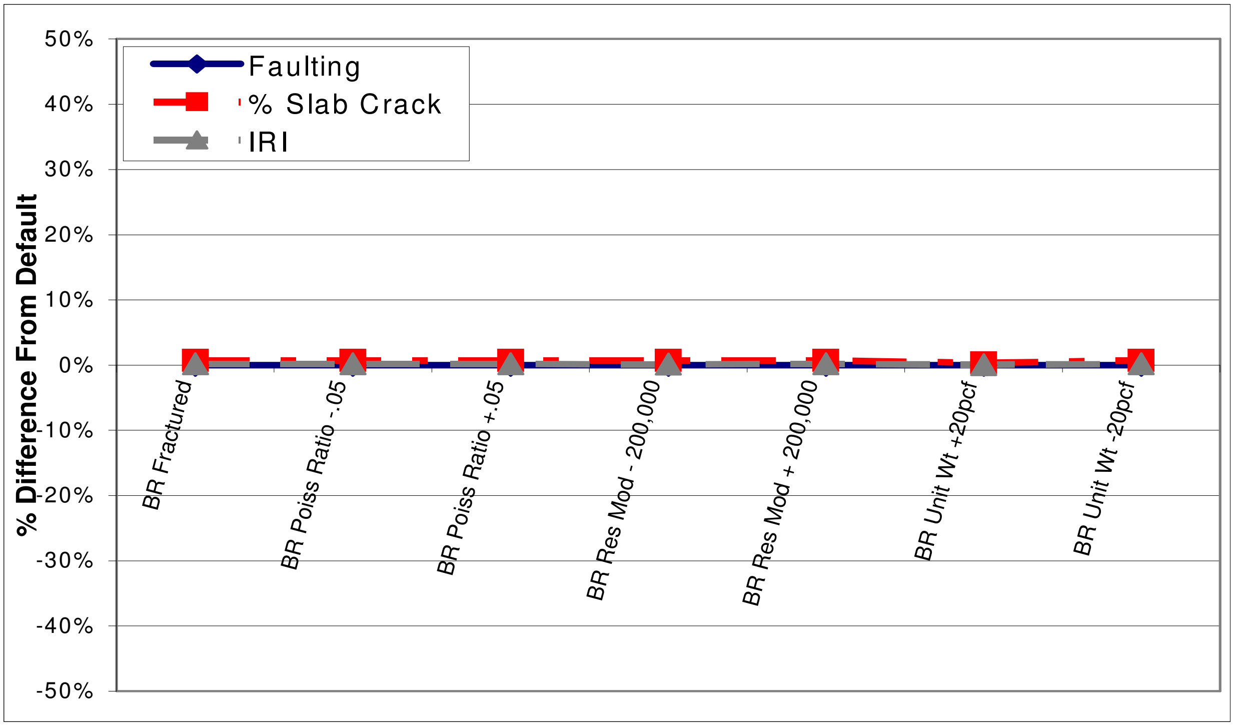

Figure K-15. JPCP, Bedrock Variables.

Table K-7. Results of JPCP, General Variables.

Description	Category	Faulting	% Slab Crack	IRI
Construction +2 Months	01-General	=	<	<
Construction +4 Months	01-General	< < <	<	< <
Construction −5 Months	01-General	< < <	=	< < <
Traffic +4 Month (More Cure)	01-General	=	>	>
Traffic −1 Month (Less Cure)	01-General	=	>	=
Initial IRI +12	02-Analysis	=	=	> >
Initial IRI −13	02-Analysis	=	=	< <
Local Road TTC Class 9	02-Site	< <	< <	< <
Minor Arterial TTC Class 4	02-Site	< <	< <	< <

Table K-8. Results of JPCP, Traffic Variables.

Description	Category	Faulting	% Slab Crack	IRI
AADT −2318 (20%)	03-Traffic	< <	< <	< <
AADT +2318 (20%)	03-Traffic	> >	> >	> >
Lane Width 2' Less	03-Traffic-General	=	=	=
Lane Width 2' More	03-Traffic-General	=	=	=
Wander 2" Less	03-Traffic-General	< <	< <	< <
Wander 2" More	03-Traffic-General	> >	> >	> >
Wheel Loca 4" Close to Lane	03-Traffic-General	> > >	> > >	> > >
Wheel Loca 4" Far to Lane	03-Traffic-General	< < <	< <	< < <
ALL Tire Press +30 psi	03-Traffic-General-Axle	=	>	>
ALL Tire Press −30 psi	03-Traffic-General-Axle	=	<	<
Dual Tire Press +30 psi	03-Traffic-General-Axle	=	>	>
Dual Tire Press −30 psi	03-Traffic-General-Axle	=	<	<
Single Tire Press +30 psi	03-Traffic-General-Axle	=	=	=
Single Tire Press −30 psi	03-Traffic-General-Axle	=	=	=

Table K-9. Results of JPCP, Climate Variables.

Description	Category	Faulting	% Slab Crack	IRI
Elevation −18'	04-Climate	=	>	=
Elevation +30'	04-Climate	=	=	=
Latitude −0.8	04-Climate	< <	< <	< <
Latitude +0.6	04-Climate	=	=	=
Longitude +1	04-Climate	< <	< <	< <
Longitude −1	04-Climate	=	< <	< <
Water Table Depth at 1'	04-Climate	< <	>	<
Water Table Depth at 50'	04-Climate	=	=	>

Table K-10. Results of JPCP, Design Variables.

Description	Category	Faulting	% Slab Crack	IRI
AC Shoulder	05-JPC Design	> > >	> > >	> > >
Bar Diameter −0.125	05-JPC Design	> > >	=	> > >
Bar Diameter +0.125	05-JPC Design	< < <	=	< < <
* Curl/Warp Temp Diff +4	05-JPC Design	< < <	> > >	>
* Curl/Warp Temp Diff −5	05-JPC Design	> > >	> > >	> > >
Decrease Erodibility	05-JPC Design	< < <	=	< <
Dowel Bar Spacing +2"	05-JPC Design	=	=	=
Dowel Bar Spacing −2"	05-JPC Design	=	=	=
Increase Erodibility	05-JPC Design	> >	=	> >
Joint Seal - None	05-JPC Design	=	=	=
Joint Seal - Silicone	05-JPC Design	=	=	=
Joint Spacing 12.5'	05-JPC Design	< < <	< < <	< < <
Joint Spacing 18'	05-JPC Design	> > >	> > >	> > >
Joint Spacing Random	05-JPC Design	>	> > >	> > >
Loss of Base Bond @24 Month	05-JPC Design	=	<	<
Loss of Base Bond @60 Month	05-JPC Design	=	<	<
Loss of Base Bond @96 Month	05-JPC Design	=	<	<
LTE −20%	05-JPC Design	> >	> > >	> > >
LTE +20%	05-JPC Design	< <	< < <	< <
No Dowels	05-JPC Design	> > >	=	> > >
Widened and Tied 12-50	05-JPC Design	> >	> > >	> > >
Widened and Tied 14-90	05-JPC Design	< < <	< <	< < <
Widened Slab 12'	05-JPC Design	=	=	=
Widened Slab 14'	05-JPC Design	< < <	< <	< < <

* - Trend seems inconsistent with engineering principles.

Table K-11. Results of JPCP, Drainage Variables.

Description	Category	Faulting	% Slab Crack	IRI
Cross Slope +2%	06-JPC-Drain	=	=	=
Cross Slope −2%	06-JPC-Drain	=	=	=
Drainage Path Length +3'	06-JPC-Drain	=	=	=
Drainage Path Length −2'	06-JPC-Drain	=	=	=
Infiltration Extreme	06-JPC-Drain	=	=	=
Infiltration Moderate	06-JPC-Drain	=	=	=
Surf Shortwave Absorp −0.05	06-JPC-Drain	< <	< <	< <
Surf Shortwave Absorp +0.05	06-JPC-Drain	> >	> > >	> >

Table K-12. Results of JPCP, JPCP Mix Variables.

Description	Category	Faulting	% Slab Crack	IRI
Basalt Aggregate	07-JPC-Mix	=	=	=
Cement Content +47 lb/yd^3	07-JPC-Mix	> >	=	> >
Cement Content −47 lb/yd^3	07-JPC-Mix	< <	=	< <
Cement Type II	07-JPC-Mix	< <	<	< <
Cement Type III	07-JPC-Mix	> >	=	>
Chert Aggregate	07-JPC-Mix	=	=	=
Days to Develop 50% +15	07-JPC-Mix	<	=	=
Days to Develop 50% −15	07-JPC-Mix	=	=	>
Granite Aggregate	07-JPC-Mix	=	=	=
Revers Shrink +25%	07-JPC-Mix	=	=	=
Revers Shrink −25%	07-JPC-Mix	<	=	=
Ultimate Shrink +99	07-JPC-Mix	> >	=	> >
Ultimate Shrink −101	07-JPC-Mix	< <	<	< <
Ultimate Shrink 601	07-JPC-Mix	=	=	=
Water/Cement Ratio −0.03	07-JPC-Mix	< <	=	<
Water/Cement Ratio +0.03	07-JPC-Mix	>	=	>
Wet Cure	07-JPC-Mix	< <	<	< <
Zero Stress Temp +19 °F	07-JPC-Mix	> >	=	> >
Zero Stress Temp 111 °F	07-JPC-Mix	<	=	<
Zero Stress Temp −21 °F	07-JPC-Mix	< < <	=	< <

Table K-13. Results of JPCP, JPCP Strength Variables.

Description	Category	Faulting	% Slab Crack	IRI
E +1000 ksi	07-JPC-Strength	> >	> > >	> > >
E −800 ksi	07-JPC-Strength	< <	< < <	< < <
Lev 2 Def Compress Strength	07-JPC-Strength	<	< < <	< <
Lev 2 High Compress Strength	07-JPC-Strength	> >	< < <	< <
Lev 2 Min Compress Strength	07-JPC-Strength	< <	> > >	> > >
Level 1 JPCP Strength-High	07-JPC-Strength	> >	< < <	< <
Level 1 JPCP Strength-Low	07-JPC-Strength	< <	< < <	< < <
Level 1 JPCP Strength-Mid	07-JPC-Strength	> >	< < <	< <
Level 3 Mr −40 psi	07-JPC-Strength	>	> > >	> > >
Level 3 Mr +50 psi	07-JPC-Strength	<	< < <	< < <

Table K-14. Results of JPCP, JPCP Thermal Variables.

Description	Category	Faulting	% Slab Crack	IRI
Heat Capacity −0.02	07-JPC-Thermal	<	>	=
Heat Capacity +0.03	07-JPC-Thermal	>	> >	>
* JPCP +1"	07-JPC-Thermal	>	< < <	< <
* JPCP −1"	07-JPC-Thermal	< <	> > >	> > >
JPCP Poisson’s Ratio −0.05	07-JPC-Thermal	< <	< < <	< <
JPCP Poisson’s Ratio +0.05	07-JPC-Thermal	> >	> > >	> > >
JPCP Unit Wt +5 pcf	07-JPC-Thermal	< <	> >	<
JPCP Unit Wt −5 pcf	07-JPC-Thermal	> >	< <	>
Thermal Conductivity −0.1	07-JPC-Thermal	>	> >	> >
Thermal Conductivity +0.1	07-JPC-Thermal	< <	< < <	< <
Thermal Mix Coeff of Contr ×4/6	07-JPC-Thermal	< < <	< < <	< < <
Thermal Mix Coeff of Contr ×9/6	07-JPC-Thermal	> > >	> > >	> > >

* - Trend seems inconsistent with engineering principles.

Table K-15. Results of JPCP, AC Binder Variables.

Description	Category	Faulting	% Slab Crack	IRI
AC Layer −1" No AC	08-AC	> > >	> > >	> > >
AC Top Layer +1"	08-AC	< <	<	< <
AC Visc Grade 10	08-AC-Binder-AC-3	=	>	=
AC Visc Grade 20	08-AC-Binder-AC-3	=	=	=
AC Visc Grade 30	08-AC-Binder-AC-3	=	=	=
AC PG Grade 64-16	08-AC-Binder-SP-3	=	=	=
AC PG Grade 76-28	08-AC-Binder-SP-3	=	=	=

Table K-16. Results of JPCP, AC General Variables.

Description	Category	Faulting	% Slab Crack	IRI
AC Air Voids +2.5%	08-AC-General	=	>	=
AC Air Voids −2%	08-AC-General	=	=	=
AC Effective Binder Content +3%	08-AC-General	=	=	=
AC Effective Binder Content −3%	08-AC-General	=	=	=
AC Heat Capacity +0.08	08-AC-General	>	>	>
AC Heat Capacity +0.17	08-AC-General	>	>>	>>
AC Poisson's Ratio −0.05	08-AC-General	=	=	=
AC Poisson's Ratio +0.05	08-AC-General	=	=	=
AC Reference Temp +5 °F	08-AC-General	=	=	=
AC Reference Temp −5 °F	08-AC-General	=	=	=
AC Thermal Conductivity −0.14	08-AC-General	<	<	<
AC Thermal Conductivity +0.14	08-AC-General	=	>	>
AC Unit Wt +6 pcf	08-AC-General	=	<	=
AC Unit Wt −6 pcf	08-AC-General	=	<	=

Table K-17. Results of JPCP, AC Mix Variables.

Description	Category	Faulting	% Slab Crack	IRI
AC % Pass #200 −2%	08-AC-Mix	=	=	=
AC % Pass #200 +2%	08-AC-Mix	=	=	=
AC % Retained #4 +10%	08-AC-Mix	=	=	=
AC % Retained #4 −10%	08-AC-Mix	=	=	=
AC % Retained 3/4" +10%	08-AC-Mix	=	=	=
AC % Retained 3/4" −10%	08-AC-Mix	=	=	=
AC % Retained 3/8" +10%	08-AC-Mix	=	=	=
AC % Retained 3/8" −10%	08-AC-Mix	=	=	=

Table K-18. Results of JPCP, Lime Modified ICM Variables.

Description	Category	Faulting	% Slab Crack	IRI
CHLS D60×2	09-CHLS-ICM	<	<	<
CHLS D60/2	09-CHLS-ICM	=	=	=
CHLS Default Soil Water Values	09-CHLS-ICM	=	<	=
CHLS Grav Water Con −2.4%	09-CHLS-ICM	=	=	>
CHLS Grav Water Con +2.6%	09-CHLS-ICM	<	<	<
CHLS High Soil Water Values	09-CHLS-ICM	<<	<	<
CHLS Low Soil Water Values	09-CHLS-ICM	<	<	=
CHLS P#4 −10%	09-CHLS-ICM	=	=	=
CHLS P#4 +5%	09-CHLS-ICM	=	=	=
CHLS P200 +10%	09-CHLS-ICM	>>	=	>
CHLS P200 −10%	09-CHLS-ICM	<	<	<
CHLS PI +4	09-CHLS-ICM	=	=	=
CHLS PI −2	09-CHLS-ICM	<	<	<
CHLS Sat Hyd Cond - Default	09-CHLS-ICM	<	<	=
CHLS Sat Hyd Cond /3.25	09-CHLS-ICM	<	<	=
CHLS Sat Hyd Cond 2×10^{-5}	09-CHLS-ICM	=	=	=
CHLS Sat Hyd Cond×1.5	09-CHLS-ICM	<	<	<
CHLS Soil Water Value Prog-Def	09-CHLS-ICM	=	=	=
CHLS Spec Grav −0.05	09-CHLS-ICM	=	=	=
CHLS Spec Grav +0.05	09-CHLS-ICM	=	=	=
CHLS Uncompacted	09-CHLS-ICM	<	<	<
CHLS Unit Wt −10 pcf	09-CHLS-ICM	<	<	<
CHLS Unit Wt +10 pcf	09-CHLS-ICM	=	>	>

Table K-19. Results of JPCP, Lime Modified Strength Variables.

Description	Category	Faulting	% Slab Crack	IRI
CH Lime Stab Layer +2"	09-CHLS-Str	>	>	>
CH Lime Stab Layer −2"	09-CHLS-Str	<<	>	<
CH LS Poisson’s Ratio −0.05	09-CHLS-Str	=	=	=
CH LS Poisson’s Ratio +0.10	09-CHLS-Str	=	=	=
CHLS Coeff of Lateral Press −0.10	09-CHLS-Str	=	=	=
CHLS Coeff of Lateral Press +0.10	09-CHLS-Str	=	=	=
CHLS Representative Values	09-CHLS-Str	=	=	=
CHLS Resilient Modulus×0.7	09-CHLS-Str	=	<	=
CHLS Resilient Modulus×1.3	09-CHLS-Str	=	>	>

Table K-20. Results of JPCP, Subgrade ICM Variables.

Description	Category	Faulting	% Slab Crack	IRI
SG D60×2	10-SG-ICM	=	>	>
SG Default Soil Water Values	10-SG-ICM	>>	>>>	>>
SG Grav Water Con −10%	10-SG-ICM	=	>	>
SG Grav Water Con +10%	10-SG-ICM	=	>	>
SG High Soil Water Values	10-SG-ICM	>>	>>>	>>>
SG Low Soil Water Values	10-SG-ICM	>>	>>>	>>
SG P200 +10%	10-SG-ICM	=	>	>
SG P200 −10%	10-SG-ICM	=	>	>
SG PI +10	10-SG-ICM	=	=	=
SG PI −10	10-SG-ICM	=	<	=
SG Rep Values Rather than ICM	10-SG-ICM	=	=	=
SG Sat Hyd Cond	10-SG-ICM	=	=	=
SG Sat Hyd Cond Prog-Def	10-SG-ICM	=	>	>
SG Sat Hyd Cond×100	10-SG-ICM	=	<	=
SG Sat Hyd Cond/100	10-SG-ICM	=	=	=
SG Soil Water Value Prog-Def	10-SG-ICM	=	>	>
SG Spec Grav −0.10	10-SG-ICM	=	>	>
SG Spec Grav +0.10	10-SG-ICM	=	>	>
SG Uncompacted	10-SG-ICM	>	>	>
SG Unit Wt +23.3 pcf	10-SG-ICM	<	<	<
SG Unit Wt −16.7 pcf	10-SG-ICM	>	>>	>>

Table K-21. Results of JPCP, Subgrade Strength Variables.

Description	Category	Faulting	% Slab Crack	IRI
SG Coeff of Lateral Press −0.10	10-SG-Str	=	>	>
SG Coeff of Lateral Press +0.10	10-SG-Str	=	=	=
SG Poisson's Ratio −0.05	10-SG-Str	<	>	=
SG Poisson's Ratio +0.05	10-SG-Str	>	>	>
SG Resilient Modulus +5 ksi	10-SG-Str	>	>	>
SG Resilient Modulus −5 ksi	10-SG-Str	<	>	=
SG Thickness +25"	10-SG-Str	<	=	<
SG Thickness −25"	10-SG-Str	>	>>	>>

Table K-22. Results of JPCP, Bedrock Variables.

Description	Category	Faulting	% Slab Crack	IRI
BR Fractured	11-BR	=	>	>
BR Poiss Ratio −0.05	11-BR	=	>	>
BR Poiss Ratio +0.05	11-BR	=	>	>
BR Res Mod −200,000 ksi	11-BR	=	>	>
BR Res Mod +200,000 ksi	11-BR	=	>	>
BR Unit Wt +20 pcf	11-BR	=	>	=
BR Unit Wt −20 pcf	11-BR	=	>	>

APPENDIX L

AC OVERLAY OF AC PAVEMENT RESULTS

Table L-1. AC Overlay of AC, Highly Significant Variables - Longitudinal Cracking.

Description	Category	Long-Rank
Local Road TTC Class 9	02-Site	0.16
Minor Arterial TTC Class 4	02-Site	0.18
All Tire Press +30 psi	03-Traffic-General-Axle	0.33
All Tire Press −30 psi	03-Traffic-General-Axle	0.20
Dual Tire Press +30 psi	03-Traffic-General-Axle	0.33
Dual Tire Press −30 psi	03-Traffic-General-Axle	0.20
Elevation +1500'	04-Climate	0.40
Water Table Depth 1'	04-Climate	0.33
All Interface ×0.3	06-Layer	0.04
All Interface ×0.8	06-Layer	0.04
CH Interface ×0.3	06-Layer	0.40
CH Interface ×0.8	06-Layer	0.40
Layer Level 2 Crack High	06-Layer	0.02
Layer Level 2 Crack Low	06-Layer	0.02
Layer Level 2 Rut	06-Layer	0.02
Layer Level 2 Rut High	06-Layer	0.02
Layer Level 2 Rut Low	06-Layer	0.02
New Interface ×0.3	06-Layer	0.03
New Interface ×0.8	06-Layer	0.03
Pavement Rating-Worse	06-Layer	0.22
AC Layer +1.0"	07-AC	0.44
AC Layer −1.0"	07-AC	0.40
AC % Pass #200 −2.5%	07-AC-Mix	0.32
AC % Retained #4 +10%	07-AC-Mix	0.34
AC % Retained #4 −10%	07-AC-Mix	0.46
AC Dynamic Mod /1.5	07-AC-Mix	0.13
AC Dynamic Mod Def	07-AC-Mix	0.35
AC Dynamic Mod ×1.5	07-AC-Mix	0.17

Table L-2. AC Overlay of AC, Significant Variables - Longitudinal Cracking.

Description	Category	Long-Rank
Construction +2 months (Cold)	01-General	1.42
Construction -5 months (Cold)	01-General	0.63
Traffic +2 months (More Cure)	01-General	1.83
Traffic −2 months (Less Cure)	01-General	1.34
AADT −193 (20%)	03-Traffic	1.06
AADT +232 (20%)	03-Traffic	0.94
Wander 2" More	03-Traffic-General	2.30
Elevation −1500'	04-Climate	0.48
Latitude +0.6	04-Climate	1.03
Longitude +1	04-Climate	2.30
Longitude −1	04-Climate	0.92
Exist Interface ×0.3	06-Layer	0.53
Exist Interface ×0.8	06-Layer	0.53
Gran Interface ×0.3	06-Layer	0.55
Gran Interface ×0.8	06-Layer	0.54
ML Interface ×0.3	06-Layer	1.34
ML Interface ×0.8	06-Layer	1.34
Pavement Rating - Better	06-Layer	1.03
AC % Pass #200 +2.5%	07-AC-Mix	0.81
AC % Retained 3/4" +2%	07-AC-Mix	2.30
AC % Retained 3/4" −3%	07-AC-Mix	1.38
AC % Retained 3/8" +8%	07-AC-Mix	1.06
AC % Retained 3/8" −7%	07-AC-Mix	0.96
AC All Gradations on Low Side	07-AC-Mix	0.52

Table L-3. AC Overlay of AC, Highly Significant Variables - Alligator Cracking.

Description	Category	Allig-Rank
ALL Tire Press +30 psi	03-Traffic-General-Axle	0.30
Dual Tire Press +30 psi	03-Traffic-General-Axle	0.30
ALL Interface ×0.3	06-Layer	0.01
ALL Interface ×0.8	06-Layer	0.01
Exist Interface ×0.3	06-Layer	0.24
Exist Interface ×0.8	06-Layer	0.24
Layer Level 2 Crack High	06-Layer	0.01
Layer Level 2 Crack Low	06-Layer	0.01
Layer Level 2 Rut	06-Layer	0.01
Layer Level 2 Rut High	06-Layer	0.01
Layer Level 2 Rut Low	06-Layer	0.01
New Interface ×0.3	06-Layer	0.01
New Interface ×0.8	06-Layer	0.01
Pavement Rating-Better	06-Layer	0.02
Pavement Rating-Worse	06-Layer	0.02
AC Layer +1.0"	07-AC	0.02
AC Layer −1.0"	07-AC	0.02
AC Dynamic Mod ×1.5	07-AC-Mix	0.38

Table L-4. AC Overlay of AC, Significant Variables - Alligator Cracking.

Description	Category	Allig-Rank
Construction +2 months (Cold)	01-General	1.18
Construction −5 months (Cold)	01-General	2.05
Local Road TTC Class 9	02-Site	0.63
Minor Arterial TTC Class 4	02-Site	1.18
AADT −193 (20%)	03-Traffic	1.18
AADT +232 (20%)	03-Traffic	0.82
Wander 2" Less	03-Traffic-General	1.18
Wander 2" More	03-Traffic-General	2.05
ALL Tire Press −30 psi	03-Traffic-General-Axle	1.18
Dual Tire Press −30 psi	03-Traffic-General-Axle	1.18
Elevation −1500'	04-Climate	2.05
Elevation +1500'	04-Climate	1.18
Latitude −0.8	04-Climate	2.05
Latitude +0.6	04-Climate	2.05
Water Table Depth 1'	04-Climate	0.52
CH Interface ×0.3	06-Layer	0.82
CH Interface ×0.8	06-Layer	0.82
Gran Interface ×0.3	06-Layer	0.52
Gran Interface ×0.8	06-Layer	0.52
ML Interface ×0.3	06-Layer	2.05
ML Interface ×0.8	06-Layer	2.05
AC % Pass #200 +2.5%	07-AC-Mix	2.05
AC % Retained #4 −10%	07-AC-Mix	2.05
AC % Retained 3/4 +2%	07-AC-Mix	2.05
AC % Retained 3/8" +8%	07-AC-Mix	2.05
AC Dynamic Mod /1.5	07-AC-Mix	2.05
AC Dynamic Mod Def	07-AC-Mix	1.18

Table L-5. AC Overlay of AC, Highly Significant Variables - AC Rutting.

Description	Category	ACRut-rank
ALL Tire Press +30 psi	03-Traffic-General-Axle	0.39
ALL Tire Press −30 psi	03-Traffic-General-Axle	0.25
Dual Tire Press +30 psi	03-Traffic-General-Axle	0.39
Dual Tire Press −30 psi	03-Traffic-General-Axle	0.25
Elevation +1500'	04-Climate	0.48
ALL Interface ×0.3	06-Layer	0.18
ALL Interface ×0.8	06-Layer	0.18
Layer Level 2 Crack High	06-Layer	0.03
Layer Level 2 Crack Low	06-Layer	0.03
Layer Level 2 Rut	06-Layer	0.03
Layer Level 2 Rut High	06-Layer	0.03
Layer Level 2 Rut Low	06-Layer	0.03
New Interface ×0.3	06-Layer	0.17
New Interface ×0.8	06-Layer	0.17
AC Dynamic Mod /1.5	07-AC-Mix	0.29
AC Dynamic Mod Def	07-AC-Mix	0.44
AC Dynamic Mod ×1.5	07-AC-Mix	0.18

Table L-6. AC Overlay of AC, Significant Variables - AC Rut Rank.

Description	Category	ACRut-rank
Construction −5 Months (Cold)	01-General	2.07
Local Road TTC Class 9	02-Site	0.66
Minor Arterial TTC Class 4	02-Site	1.73
AADT −193 (20%)	03-Traffic	1.05
AADT +232 (20%)	03-Traffic	0.95
Wander 2" Less	03-Traffic-General	1.49
Elevation −1500'	04-Climate	0.53
Latitude +0.6	04-Climate	0.81
Longitude +1	04-Climate	2.07
Longitude −1	04-Climate	1.05
Exist Interface ×0.3	06-Layer	1.73
Exist Interface ×0.8	06-Layer	1.73
Gran Interface ×0.3	06-Layer	2.07
Gran Interface ×0.8	06-Layer	2.07
Pavement Rating-Worse	06-Layer	2.07
AC Layer +1.0"	07-AC	1.73
AC Layer −1.0"	07-AC	1.30
AC % Pass #200 −2.5%	07-AC-Mix	0.66
AC % Pass #200 +2.5%	07-AC-Mix	1.30
AC % Retained #4 +10%	07-AC-Mix	0.70
AC % Retained #4 −10%	07-AC-Mix	0.75
AC % Retained 3/8" +8%	07-AC-Mix	1.73
AC % Retained 3/8" −7%	07-AC-Mix	2.07
AC All Gradations on Low Side	07-AC-Mix	1.05

Table L-7. AC Overlay of AC, Highly Significant Variables - Total Rutting Rank.

Description	Category	TotR-Rank
All Tire Press +30 psi	03-Traffic-General-Axle	0.39
All Tire Press −30 psi	03-Traffic-General-Axle	0.25
Dual Tire Press +30 psi	03-Traffic-General-Axle	0.39
Dual Tire Press −30 psi	03-Traffic-General-Axle	0.25
Elevation +1500'	04-Climate	0.48
All Interface ×0.3	06-Layer	0.17
All Interface ×0.8	06-Layer	0.17
Layer Level 2 Crack High	06-Layer	0.02
Layer Level 2 Crack Low	06-Layer	0.02
Layer Level 2 Rut	06-Layer	0.02
Layer Level 2 Rut High	06-Layer	0.02
Layer Level 2 Rut Low	06-Layer	0.02
New Interface ×0.3	06-Layer	0.17
New Interface ×0.8	06-Layer	0.17
AC Dynamic Mod /1.5	07-AC-Mix	0.29
AC Dynamic Mod Def	07-AC-Mix	0.44
AC Dynamic Mod x1.5	07-AC-Mix	0.18

Table L-8. AC Overlay of AC, Significant Variables - Total Rutting Rank.

Description	Category	TotR-Rank
Construction −5 months (Cold)	01-General	2.07
Local Road TTC Class 9	02-Site	0.66
Minor Arterial TTC Class 4	02-Site	1.73
AADT −193 (20%)	03-Traffic	1.05
AADT +232 (20%)	03-Traffic	0.95
Wander 2" Less	03-Traffic-General	1.49
Elevation −1500'	04-Climate	0.53
Latitude +0.6	04-Climate	0.81
Longitude +1	04-Climate	2.07
Longitude −1	04-Climate	1.05
Exist Interface ×0.3	06-Layer	1.73
Exist Interface ×0.8	06-Layer	1.73
Gran Interface ×0.3	06-Layer	2.07
Gran Interface ×0.8	06-Layer	2.07
Pavement Rating-Worse	06-Layer	2.07
AC Layer +1.0"	07-AC	1.73
AC Layer −1.0"	07-AC	1.30
AC % Pass #200 −2.5%	07-AC-Mix	0.66
AC % Pass #200 +2.5%	07-AC-Mix	1.30
AC % Retained #4 +10%	07-AC-Mix	0.70
AC % Retained #4 −10%	07-AC-Mix	0.75
AC % Retained 3/8" +8%	07-AC-Mix	1.73
AC % Retained 3/8" −7%	07-AC-Mix	2.07
AC All Gradations on Low Side	07-AC-Mix	1.05

Table L-9. AC Overlay of AC, Highly Significant Variables - IRI Rank.

Description	Category	IRI-Rank
Layer Level 2 Crack High	06-Layer	0.00
Layer Level 2 Crack Low	06-Layer	0.00
Layer Level 2 Rut	06-Layer	0.00
Layer Level 2 Rut High	06-Layer	0.00
Layer Level 2 Rut Low	06-Layer	0.00
ALL Interface ×0.3	06-Layer	0.00
ALL Interface ×0.8	06-Layer	0.00
New Interface ×0.3	06-Layer	0.00
New Interface ×0.8	06-Layer	0.00
Pavement Rating-Worse	06-Layer	0.05
AC Dynamic Mod ×1.5	07-AC-Mix	0.19
AC Dynamic Mod Def	07-AC-Mix	0.40
Pavement Rating-Better	06-Layer	0.48
ALL Tire Press +30 psi	03-Traffic-General-Axle	0.48
Dual Tire Press +30 psi	03-Traffic-General-Axle	0.48

Table L-10. AC Overlay of AC, Significant Variables - IRI Rank.

Description	Category	IRI-Rank
All Tire Press −30 psi	03-Traffic-General-Axle	0.60
Dual Tire Press −30 psi	03-Traffic-General-Axle	0.60
AC Layer −1.0"	07-AC	0.80
Local Road TTC Class 9	02-Site	0.80
AADT +232 (20%)	03-Traffic	0.80
AC % Pass #200 +2.5%	07-AC-Mix	0.80
AC % Retained #4 −10%	07-AC-Mix	0.80
AC % Retained 3/4" +2%	07-AC-Mix	0.80
AC % Retained 3/8" +8%	07-AC-Mix	0.80
Construction −5 Months (Cold)	01-General	0.80
Elevation +1500'	04-Climate	0.80
Exist Interface ×0.3	06-Layer	0.80
Exist Interface ×0.8	06-Layer	0.80
Wander 2" Less	03-Traffic-General	0.80

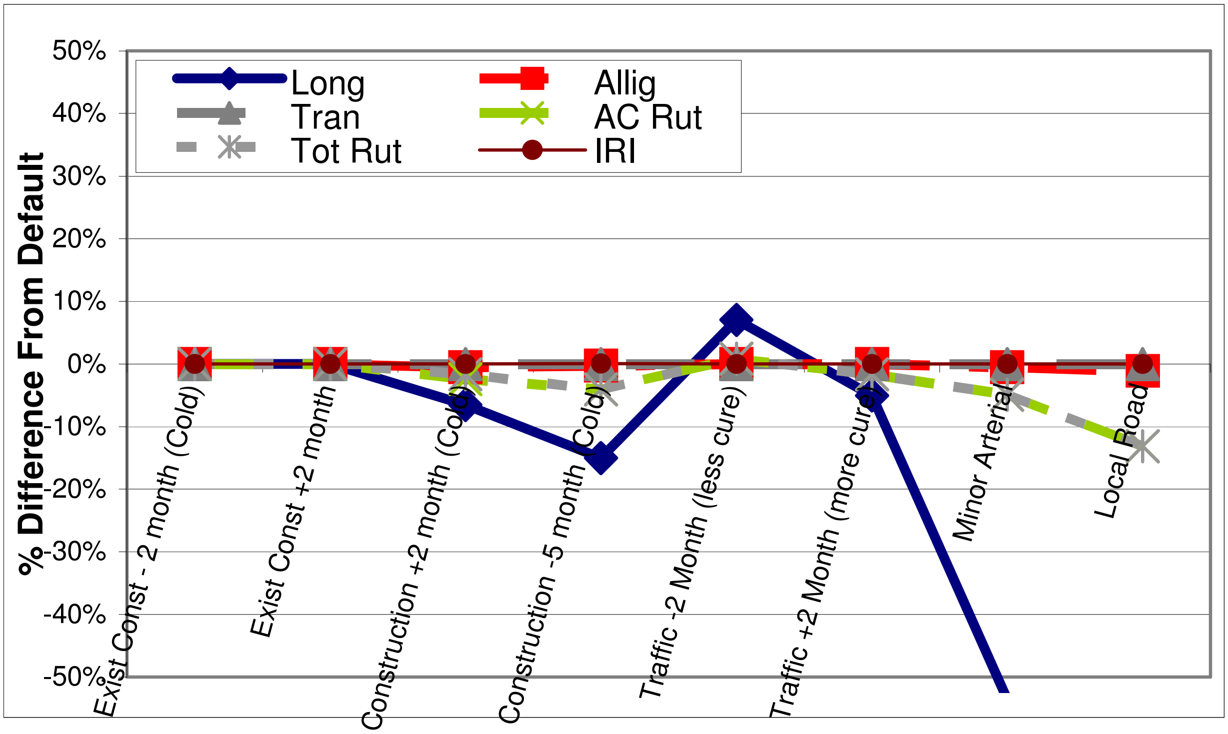

Figure L-1. AC Overlay of AC, General Variables.

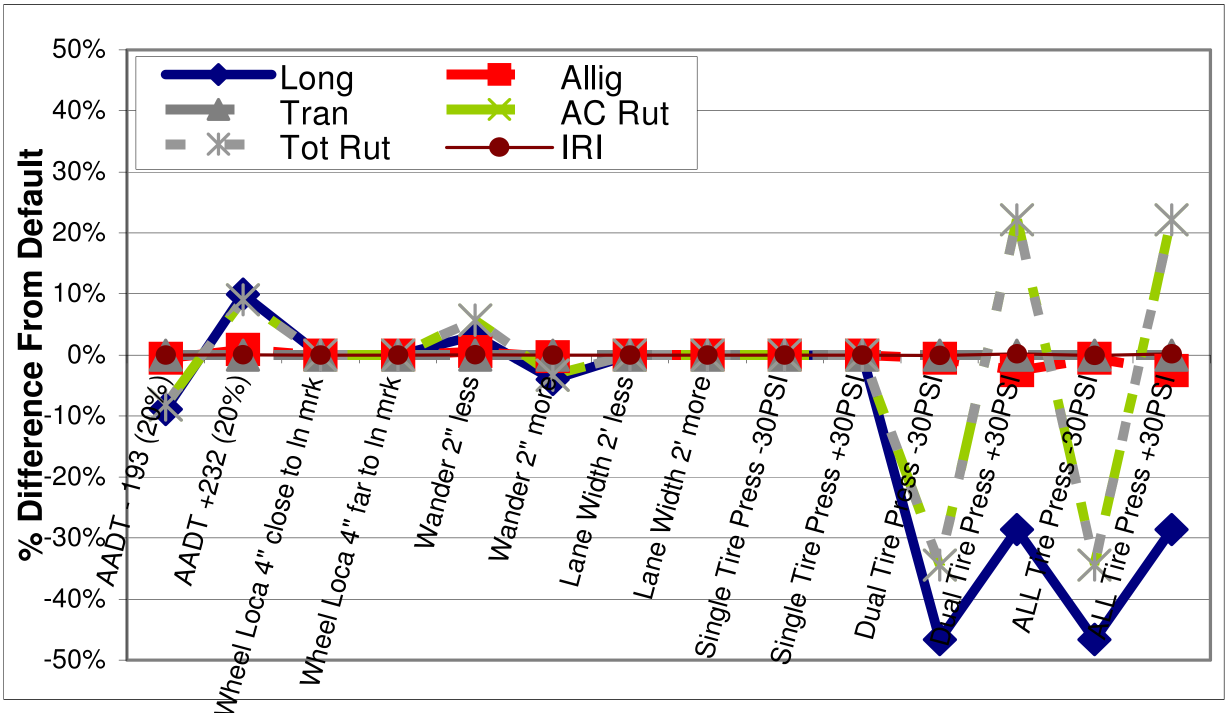

Figure L-2. AC Overlay of AC, Traffic Variables.

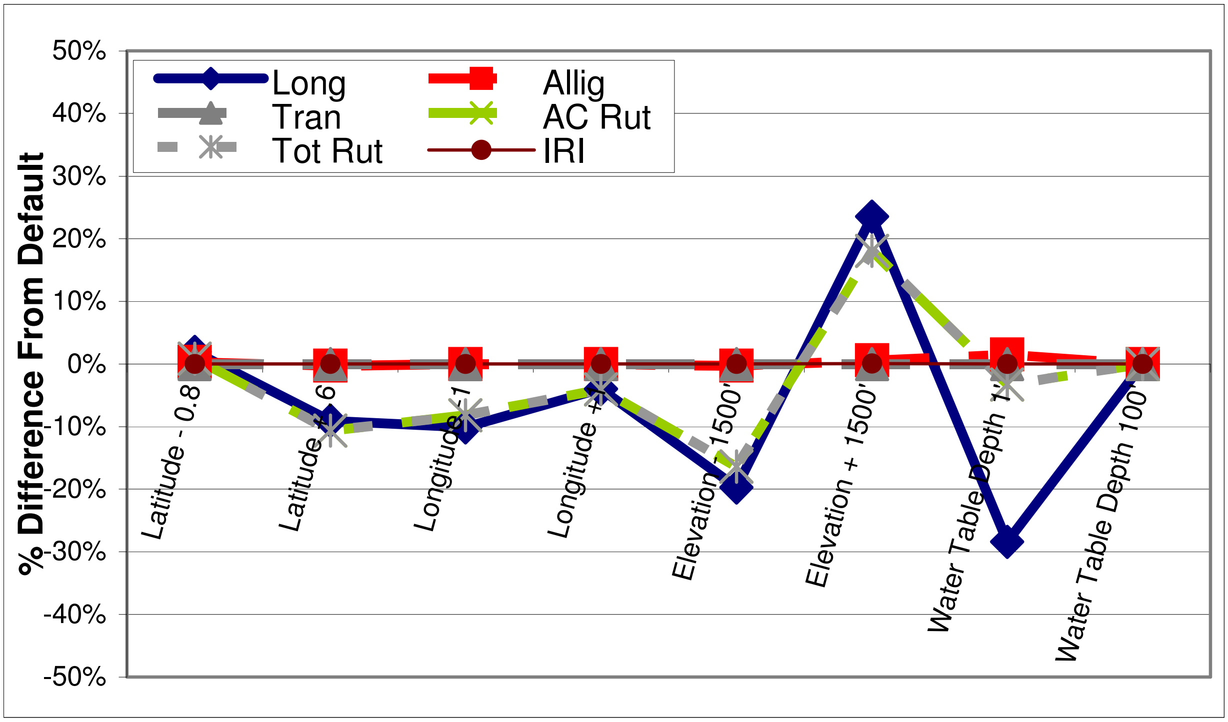

Figure L-3. AC Overlay of AC, Climate Variables.

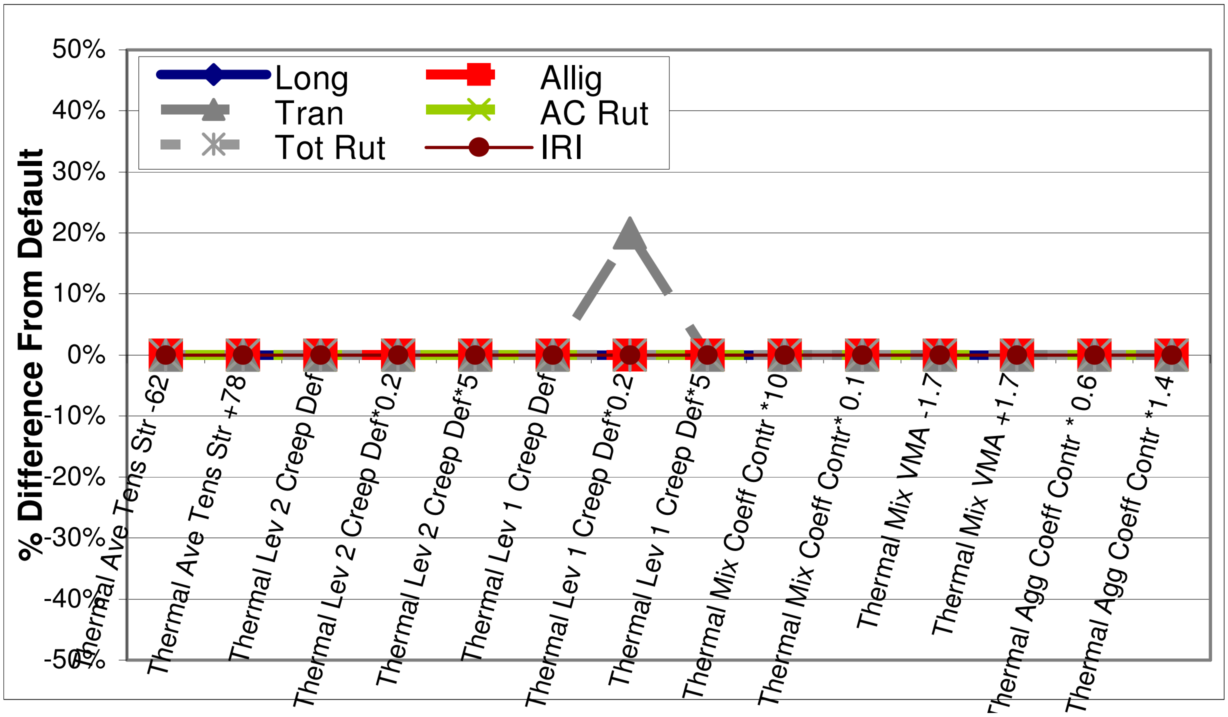

Figure L-4. AC Overlay of AC, Thermal Variables.

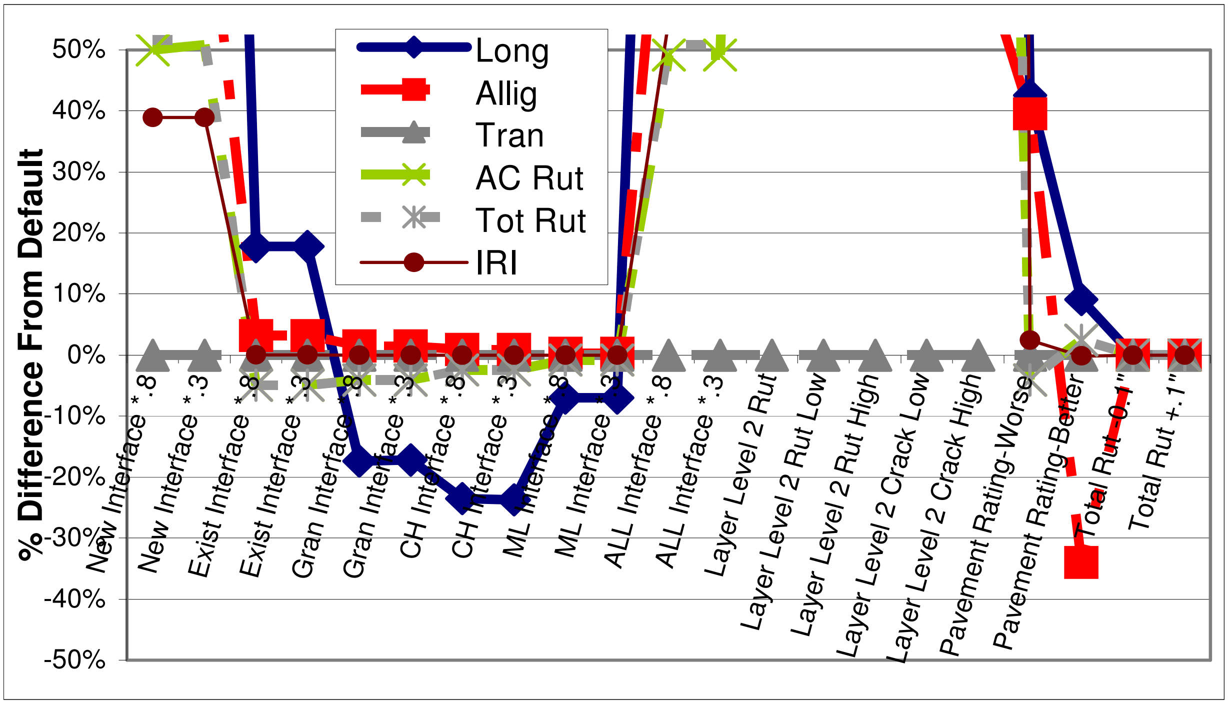

Figure L-5. AC Overlay of AC, AC Layer Variables.

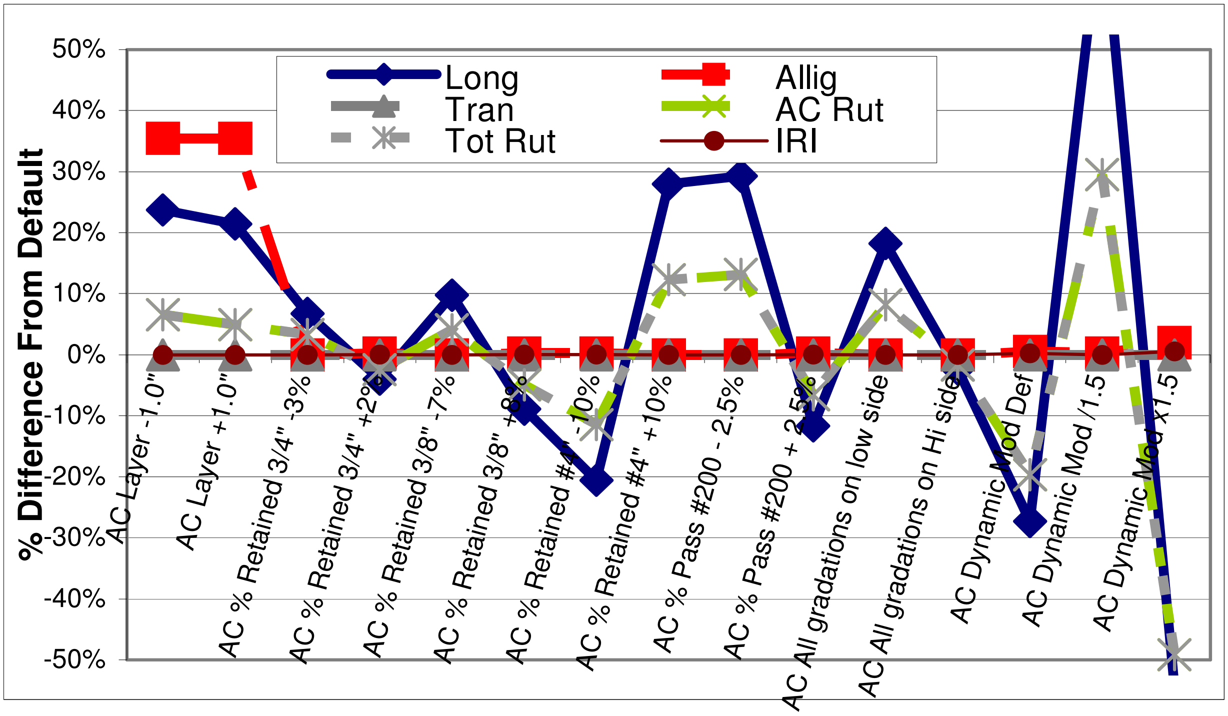

Figure L-6. AC Overlay of AC, AC Mix Variables.

Table L-11. Results of AC Overlay of AC, General Variables.

Description	Long	Allig	AC Rut	Tot Rut	IRI
Construction +2 months (Cold)	<<	<<	<	<	=
Construction −5 months (Cold)	<<	<<	<<	<<	>>
Exist Const −2 months	=	=	=	=	=
Exist Const +2 months	=	=	=	=	=
Traffic +2 month (More Cure)	<<	=	<	<	=
Traffic −2 month (Less Cure)	>>	=	>	>	=
Local Road TTC Class 9	<<<	<<	<<	<<	<<
Minor Arterial TTC Class 4	<<<	<<	<<	<<	=

Table L-12. Results of AC Overlay of AC, Traffic Variables.

Description	Long	Allig	AC Rut	Tot Rut	IRI
AADT −193 (20%)	<<	<<	<<	<<	=
AADT +232 (20%)	>>	>>	>>	>>	>>
Lane Width 2' Less	=	=	=	=	=
Lane Width 2' More	=	=	=	=	=
Wander 2" Less	>	>>	>>	>>	>>
Wander 2" More	<<	<<	<	<	=
Wheel Loca 4" Close to Ln Mrk	=	=	=	=	=
Wheel Loca 4" Far to Ln Mrk	=	=	=	=	=
All Tire Press +30 psi	<<<	<<<	>>>	>>>	>>>
All Tire Press −30 psi	<<<	<<	<<<	<<<	<<
Dual Tire Press +30 psi	<<<	<<<	>>>	>>>	>>>
Dual Tire Press −30 psi	<<<	<<	<<<	<<<	<<
Single Tire Press +30 psi	=	=	=	=	=
Single Tire Press −30 psi	=	=	=	=	=

Table L-13. Results of AC Overlay of AC, Climate Variables.

Description	Long	Allig	AC Rut	Tot Rut	IRI
Elevation −1500'	< < <	< <	< <	< <	=
Elevation +1500'	> > >	> >	> > >	> > >	> >
Latitude −0.8	>	> >	>	>	=
Latitude +0.6	< <	< <	< <	< <	=
Longitude +1	< <	=	< <	< <	=
Longitude −1	< <	=	< <	< <	=
Water Table Depth 1'	< < <	> >	<	<	=
Water Table Depth 100'	=	=	=	=	=

Table L-14. Results of AC Overlay of AC, Thermal Variables.

Description	Long	Allig	AC Rut	Tot Rut	IRI
Thermal Agg Coeff Contr × 0.6	=	=	=	=	=
Thermal Agg Coeff Contr ×1.4	=	=	=	=	=
Thermal Ave Tens Str +78	=	=	=	=	=
Thermal Ave Tens Str −62	=	=	=	=	=
Thermal Lev 1 Creep Def	=	=	=	=	=
Thermal Lev 1 Creep Def×0.2	=	=	=	=	=
Thermal Lev 1 Creep Def×5	=	=	=	=	=
Thermal Lev 2 Creep Def	=	=	=	=	=
Thermal Lev 2 Creep Def×0.2	=	=	=	=	=
Thermal Lev 2 Creep Def×5	=	=	=	=	=
Thermal Mix Coeff Contr ×10	=	=	=	=	=
Thermal Mix Coeff Contr× 0.1	=	=	=	=	=
Thermal Mix VMA +1.7%	=	=	=	=	=
Thermal Mix VMA −1.7%	=	=	=	=	=

Table L-15. Results of AC Overlay of AC, AC Layer Variables.

Description	Long	Allig	AC Rut	Tot Rut	IRI
ALL Interface ×0.3	>>>	>>>	>>>	>>>	>>>
ALL Interface ×0.8	>>>	>>>	>>>	>>>	>>>
CH Interface ×0.3	<<<	>>	<	<	=
CH Interface ×0.8	<<<	>>	<	<	=
Exist Interface ×0.3	>>	>>>	<<	<<	>>
Exist Interface ×0.8	>>	>>>	<<	<<	>>
Gran Interface ×0.3	<<	>>	<<	<<	=
Gran Interface ×0.8	<<	>>	<<	<<	=
Layer Level 2 Crack High	>>>	>>>	>>>	>>>	>>>
Layer Level 2 Crack Low	>>>	>>>	>>>	>>>	>>>
Layer Level 2 Rut	>>>	>>>	>>>	>>>	>>>
Layer Level 2 Rut High	>>>	>>>	>>>	>>>	>>>
Layer Level 2 Rut Low	>>>	>>>	>>>	>>>	>>>
ML Interface ×0.3	<<	>>	<	<	=
ML Interface ×0.8	<<	>>	<	<	=
New Interface ×0.3	>>>	>>>	>>>	>>>	>>>
New Interface ×0.8	>>>	>>>	>>>	>>>	>>>
Pavement Rating-Better	>>	<<<	>	>	<<<
Pavement Rating-Worse	>>>	>>>	<<	<<	>>>
Total Rut +.1"	=	=	=	=	=
Total Rut −0.1"	=	=	=	=	=

Table L-16. Results of AC Overlay of AC, AC Mix Variables.

Description	Long	Allig	AC Rut	Tot Rut	IRI
AC Layer +1.0"	>>>	>>>	>>	>>	=
AC Layer −1.0"	>>>	>>>	>>	>>	<<
AC % Pass #200 −2.5%	>>>	=	>>	>>	=
AC % Pass #200 +2.5%	<<	>>	<<	<<	>>
AC % Retained #4 +10%	>>>	=	>>	>>	=
AC % Retained #4 −10%	<<<	>>	<<	<<	>>
AC % Retained 3/4" +2%	<<	>>	<	<	>>
AC % Retained 3/4" −3%	>>	=	>	>	=
AC % Retained 3/8" +8%	<<	>>	<<	<<	>>
AC % Retained 3/8" −7%	>>	=	>>	>>	=
AC All Gradations on Hi Side	<	=	<	<	=
AC All Gradations on Low Side	>>	=	>>	>>	=
AC Dynamic Mod /1.5	>>>	>>	>>>	>>>	=
AC Dynamic Mod Def	<<<	>>	<<<	<<<	>>>
AC Dynamic Mod ×1.5	<<<	>>>	<<<	<<<	>>>

APPENDIX M

DRY-COLD, CRCP BONDED OVERLAY RESULTS

Table M-1. Dry-Cold, CRCP Bonded Overlay, Highly Significant Variables - Damage.

Description	Category	Damage Rank
Wheel Loca 4" Close to Lane	03-Traffic-General	0.1
Bar Diameter +0.125 All PCC	06-Design	0.0
Curl/Warp Temp Diff +4 All PCC	06-Design	0.3
Curl/Warp Temp Diff −5 All PCC	06-Design	0.1
Mean Crack Spacing +24 All PCC	06-Design	0.0
Steel % −0.2% All PCC	06-Design	0.0
Overlay Ultimate Shrink +157	08-CRC-Mix	0.0
Overlay Zero Stress Temp +23 Degrees	08-CRC-Mix	0.1
Exist Lev 1 CRC Strength-High	08-CRC-Strength	0.2
Overlay Lev 1 CRC Strength-Low	08-CRC-Strength	0.0
Overlay Lev 1 CRC Strength-Mid	08-CRC-Strength	0.0
Overlay Lev 2 High Compress Strength	08-CRC-Strength	0.3
Overlay Lev 2 Min Compress Strength	08-CRC-Strength	0.0
Overlay Level 3 Mr −40	08-CRC-Strength	0.1
Overlay Level 3 Mr +50	08-CRC-Strength	0.3
Exist CRC Thick +2"	08-CRC-Thermal	0.5
Exist CRC Thick −2"	08-CRC-Thermal	0.0
Overlay Coeff Contract +3	08-CRC-Thermal	0.0
Overlay Coeff Contract −2	08-CRC-Thermal	0.2
Overlay Unit Wt −5pcf	08-CRC-Thermal	0.4
SG Resilient Modulus/2	11-SG-Strength	0.4
SG Resilient Modulus×1.5	11-SG-Strength	0.3
SG Thickness +50"	11-SG-Strength	0.4
SG Thickness −50"	11-SG-Strength	0.1
Mod Subg React Deflt 1000	13-Rehabilitation	0.4
Mod Subg React Deflt −200	13-Rehabilitation	0.3
Mod Subg React Deflt −400	13-Rehabilitation	0.2
Mod Subg React Deflt −900	13-Rehabilitation	0.2
Mod Subg React Deflt −950	13-Rehabilitation	0.2
Mod Subg React Deflt −975	13-Rehabilitation	0.2
Month Meas +2	13-Rehabilitation	0.4
Month Meas −2	13-Rehabilitation	0.3

Table M-2. Dry-Cold, CRCP Bonded Overlay, Significant Variables - Damage.

Description	Category	Damage Rank
AADT −1600 (20%)	03-Traffic	1.1
AADT +1600 (20%)	03-Traffic	0.9
Exist Unit Wt −5pcf	03-Traffic-General	1.6
Wander 2" Less	03-Traffic-General	1.4
Wander 2" More	04-Climate	2.0
Water Table Depth at 1'	04-Climate	0.9
Water Table Depth at 100'	04-Climate	2.4
Steel at 1/4 depth All PCC	06-Design	1.5
Infiltration-Negligible All PCC	07-Drain	0.7
Overlay Cement Content +47lb/yd3	08-CRC-Mix	1.5
Wheel Loca 4" Far to lane	08-CRC-Mix	0.6
Exist Lev 1 CRC Strength-Mid	08-CRC-Strength	2.5
Exist Lev 2 High Compress Strength	08-CRC-Strength	2.3
Exist Lev 2 Min Compress Strength	08-CRC-Strength	0.6
Exist Level 3 Mr −40	08-CRC-Strength	1.4
Exist Level 3 Mr +50	08-CRC-Strength	0.9
Overlay Lev 1 CRC Strength-High	08-CRC-Strength	0.8
Overlay Lev 2 Def Compress Strength	08-CRC-Strength	1.0
Exist Therm Conduct −0.10	08-CRC-Thermal	2.0
Exist Therm Conduct +0.20	08-CRC-Thermal	1.2
Exist Unit Wt +5pcf	08-CRC-Thermal	1.4
Overlay CRC Thick +1"	08-CRC-Thermal	0.6
Overlay CRC Thick −1/2"	08-CRC-Thermal	0.7
Overlay Poisson Ratio −0.05	08-CRC-Thermal	0.8
Overlay Poisson Ratio + 0.05	08-CRC-Thermal	0.6
Overlay Unit Wt +5pcf	08-CRC-Thermal	0.7
Surf Shortwave Absorp +0.05 All PCC	08-CRC-Thermal	2.5
AC Layer +1"	09-AC-Mix	1.9
Lime Stab Layer +2"	10-LS-Strength	2.2
LS Resilient Modulus×2	10-LS-Strength	0.7
LS Resilient Modulus/3	10-LS-Strength	0.6
SG High Soil Water Values	11-SG-ICM	1.8
SG Unit Wt −20pcf	11-SG-ICM	0.9
SG Poisson's Ratio −0.05	11-SG-Strength	1.1
SG Poisson's Ratio +0.15	11-SG-Strength	0.5

Table M-3. Dry-Cold, CRCP Bonded Overlay, Highly Significant Variables - Punchouts.

Description	Category	Punchouts Rank
Wheel Loca 4" Close to Lane	03-Traffic-General	0.2
Bar Diameter +0.125 All PCC	06-Design	0.1
Curl/Warp Temp Diff +4 All PCC	06-Design	0.3
Curl/Warp Temp Diff −5 All PCC	06-Design	0.2
Mean Crack Spacing +24 All PCC	06-Design	0.0
Steel % −0.2% All PCC	06-Design	0.0
Overlay Ultimate Shrink +157	08-CRC-Mix	0.1
Overlay Zero Stress Temp +23 Degrees	08-CRC-Mix	0.1
Wheel Loca 4" Far to Lane	08-CRC-Mix	0.5
Exist Lev 1 CRC Strength-High	08-CRC-Strength	0.2
Exist Lev 2 Min Compress Strength	08-CRC-Strength	0.5
Overlay Lev 1 CRC Strength-Low	08-CRC-Strength	0.0
Overlay Lev 1 CRC Strength-Mid	08-CRC-Strength	0.1
Overlay Lev 2 High Compress Strength	08-CRC-Strength	0.1
Overlay Lev 2 Min Compress Strength	08-CRC-Strength	0.1
Overlay Level 3 Mr −40psi	08-CRC-Strength	0.2
Overlay Level 3 Mr +50psi	08-CRC-Strength	0.2
Exist CRC Thick +2"	08-CRC-Thermal	0.4
Exist CRC Thick −2"	08-CRC-Thermal	0.1
Overlay Coeff Contract +3	08-CRC-Thermal	0.1
Overlay Coeff Contract −2	08-CRC-Thermal	0.1
SG Resilient Modulus/2	11-SG-Strength	0.3
SG Resilient Modulus×1.5	11-SG-Strength	0.4
SG Thickness +50"	11-SG-Strength	0.3
SG Thickness −50"	11-SG-Strength	0.1
Mod Subg React Deflt 1000	13-Rehabilitation	0.3
Mod Subg React Deflt −200	13-Rehabilitation	0.2
Mod Subg React Deflt −400	13-Rehabilitation	0.1
Mod Subg React Deflt −900	13-Rehabilitation	0.1
Mod Subg React Deflt −950	13-Rehabilitation	0.1
Mod Subg React Deflt −975	13-Rehabilitation	0.1
Month Meas +2	13-Rehabilitation	0.3
Month Meas −2	13-Rehabilitation	0.2

Table M-4. Dry-Cold, CRCP Bonded Overlay, Significant Variables - Punchouts.

Description	Category	Punchouts Rank
AADT −1600 (20%)	03-Traffic	1.0
AADT +1600 (20%)	03-Traffic	1.0
Exist Unit Wt −5pcf	03-Traffic-General	1.5
Wander 2" Less	03-Traffic-General	1.3
Wander 2" More	04-Climate	2.1
Water Table Depth at 1'	04-Climate	0.8
Water Table Depth at 100'	04-Climate	2.3
Steel at 1/4 Depth All PCC	06-Design	1.6
Infiltration-Negligible All PCC	07-Drain	0.8
Overlay Cement Content +47lb/yd3	08-CRC-Mix	1.6
Exist Lev 2 High Compress Strength	08-CRC-Strength	2.4
Exist Level 3 Mr −40psi	08-CRC-Strength	1.3
Exist Level 3 Mr +50psi	08-CRC-Strength	1.0
Overlay Lev 1 CRC Strength-High	08-CRC-Strength	0.7
Overlay Lev 2 Def Compress Strength	08-CRC-Strength	0.9
Exist Therm Conduct −0.10	08-CRC-Thermal	2.1
Exist Therm Conduct +0.20	08-CRC-Thermal	1.1
Exist Unit Wt +5pcf	08-CRC-Thermal	1.5
Overlay CRC Thick +1"	08-CRC-Thermal	0.6
Overlay CRC Thick −1/2"	08-CRC-Thermal	0.7
Overlay Poisson Ratio −.05	08-CRC-Thermal	0.7
Overlay Poisson Ratio +0.05	08-CRC-Thermal	0.7
Overlay Unit Wt +5pcf	08-CRC-Thermal	0.6
Overlay Unit Wt −5pcf	08-CRC-Thermal	0.5
AC Layer +1"	09-AC-Mix	2.0
Lime Stab Layer +2"	10-LS-Strength	2.2
LS Resilient Modulus×2	10-LS-Strength	0.8
LS Resilient Modulus/3	10-LS-Strength	0.5
SG High Soil Water Values	11-SG-ICM	1.9
SG Poisson's Ratio −0.05	11-SG-Strength	1.0
SG Poisson's Ratio +0.15	11-SG-Strength	0.6
SG Unit Wt −20pcf	11-SG-ICM	1.0

Table M-5. Dry-Cold, CRCP Bonded Overlay, Highly Significant Variables - IRI.

Description	Category	IRI Rank
Wheel Loca 4" Close to Lane	03-Traffic-General	0.2
Bar Diameter +0.125 All PCC	06-Design	0.1
Curl/Warp Temp Diff +4 All PCC	06-Design	0.3
Curl/Warp Temp Diff −5 All PCC	06-Design	0.2
Mean Crack Spacing +24 All PCC	06-Design	0.1
Steel % −0.2% All PCC	06-Design	0.0
Overlay Ultimate Shrink +157	08-CRC-Mix	0.1
Overlay Zero Stress Temp +23 Degrees	08-CRC-Mix	0.1
Wheel Loca 4" Far to Lane	08-CRC-Mix	0.5
Exist Lev 1 CRC Strength-High	08-CRC-Strength	0.2
Exist Lev 2 Min Compress Strength	08-CRC-Strength	0.5
Overlay Lev 1 CRC Strength-Low	08-CRC-Strength	0.0
Overlay Lev 1 CRC Strength-Mid	08-CRC-Strength	0.1
Overlay Lev 2 High Compress Strength	08-CRC-Strength	0.1
Overlay Lev 2 Min Compress Strength	08-CRC-Strength	0.1
Overlay Level 3 Mr −40psi	08-CRC-Strength	0.2
Overlay Level 3 Mr +50psi	08-CRC-Strength	0.2
Exist CRC Thick +2"	08-CRC-Thermal	0.4
Exist CRC Thick −2"	08-CRC-Thermal	0.1
Overlay Coeff Contract +3	08-CRC-Thermal	0.1
Overlay Coeff Contract −2	08-CRC-Thermal	0.1
SG Resilient Modulus/2	11-SG-Strength	0.3
SG Resilient Modulus×1.5	11-SG-Strength	0.4
SG Thickness +50"	11-SG-Strength	0.3
SG Thickness −50"	11-SG-Strength	0.1
Mod Subg React Deflt 1000	13-Rehabilitation	0.3
Mod Subg React Deflt −200	13-Rehabilitation	0.2
Mod Subg React Deflt −400	13-Rehabilitation	0.1
Mod Subg React Deflt −900	13-Rehabilitation	0.1
Mod Subg React Deflt −950	13-Rehabilitation	0.1
Mod Subg React Deflt −975	13-Rehabilitation	0.1
Month Meas +2	13-Rehabilitation	0.3
Month Meas −2	13-Rehabilitation	0.2

Table M-6. Dry-Cold, CRCP Bonded Overlay, Significant Variables - IRI.

Description	Category	IRI Rank
AADT −1600 (20%)	03-Traffic	1.0
AADT +1600 (20%)	03-Traffic	1.0
Exist Unit Wt −5pcf	03-Traffic-General	1.6
Wander 2" Less	03-Traffic-General	1.3
Elevation −1500'	04-Climate	0.8
Elevation +1500'	04-Climate	1.6
Latitude +1.0	04-Climate	0.8
Wander 2" More	04-Climate	1.9
Water Table Depth at 1'	04-Climate	0.8
Water Table Depth at 100'	04-Climate	2.3
Steel at 1/4 Depth All PCC	06-Design	1.5
Infiltration-Negligible All PCC	07-Drain	0.8
Overlay Cement Content +47lb/yd3	08-CRC-Mix	1.5
Exist Lev 1 CRC Strength-Mid	08-CRC-Strength	2.3
Exist Lev 2 High Compress Strength	08-CRC-Strength	2.3
Exist Level 3 Mr −40psi	08-CRC-Strength	1.3
Exist Level 3 Mr +50psi	08-CRC-Strength	1.0
Overlay Lev 1 CRC Strength-High	08-CRC-Strength	0.7
Overlay Lev 2 Def Compress Strength	08-CRC-Strength	0.9
Exist Therm Conduct −0.10	08-CRC-Thermal	1.9
Exist Therm Conduct +0.20	08-CRC-Thermal	1.2
Exist Unit Wt +5pcf	08-CRC-Thermal	1.5
Overlay CRC Thick +1"	08-CRC-Thermal	0.6
Overlay CRC Thick −1/2"	08-CRC-Thermal	0.7
Overlay Poisson Ratio −0.05	08-CRC-Thermal	0.7
Overlay Poisson Ratio +0.05	08-CRC-Thermal	0.7
Overlay Unit Wt +5pcf	08-CRC-Thermal	0.6
Overlay Unit Wt −5pcf	08-CRC-Thermal	0.5
Surf Shortwave Absorp +0.05 All PCC	08-CRC-Thermal	2.3
AC Layer +1"	09-AC-Mix	1.9
Lime Stab Layer +2"	10-LS-Strength	2.1
LS Resilient Modulus×2	10-LS-Strength	0.8
LS Resilient Modulus/3	10-LS-Strength	0.5
SG High Soil Water Values	11-SG-ICM	1.8
SG Poisson's Ratio −0.05	11-SG-Strength	1.0
SG Poisson's Ratio +0.15	11-SG-Strength	0.6
SG Unit Wt −20pcf	11-SG-ICM	1.0

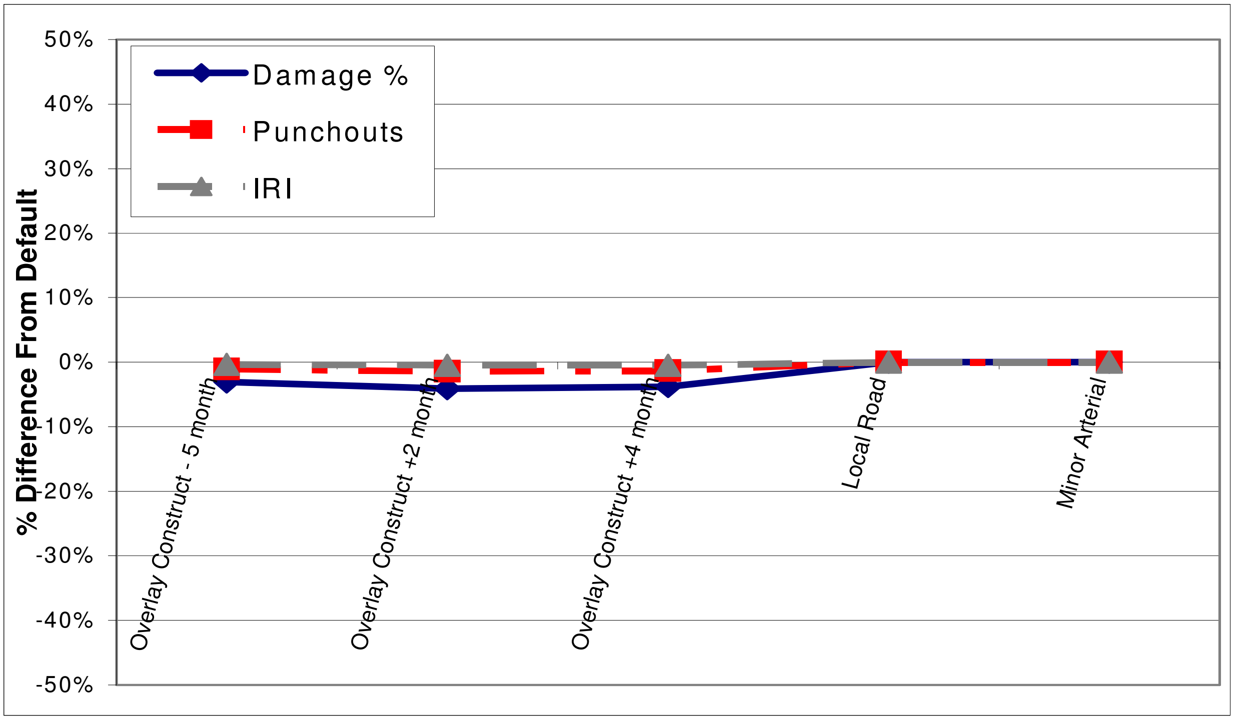

Figure M-1. Dry-Cold, CRCP Bonded Overlay General Variables.

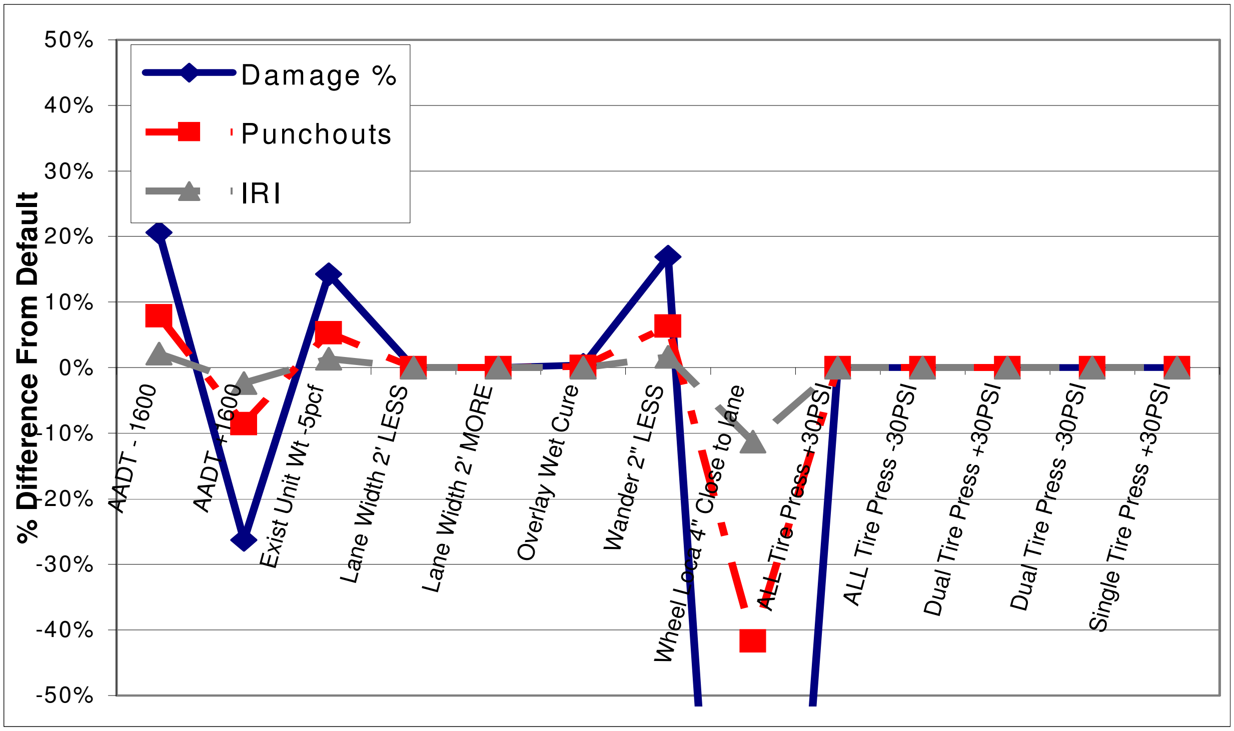

Figure M-2. Dry-Cold, CRCP Bonded Overlay, Traffic Variables.

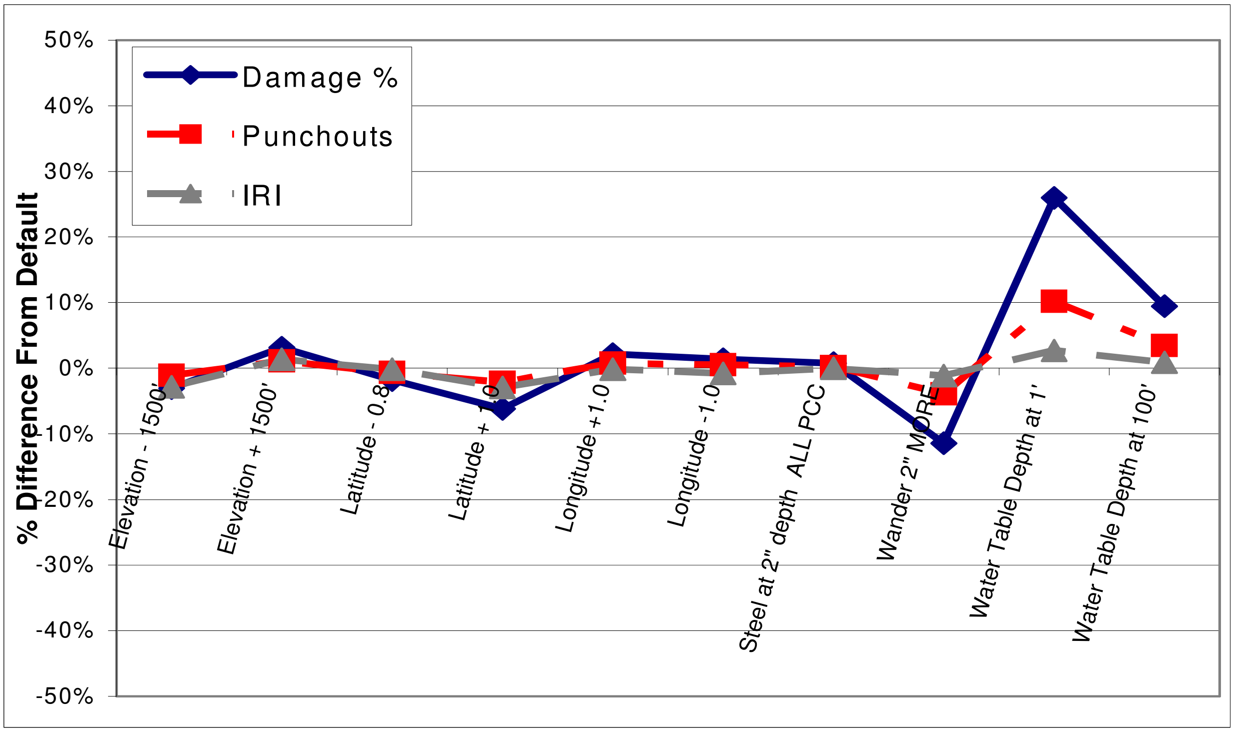

Figure M-3. Dry-Cold, CRCP Bonded Overlay, Climate Variables.

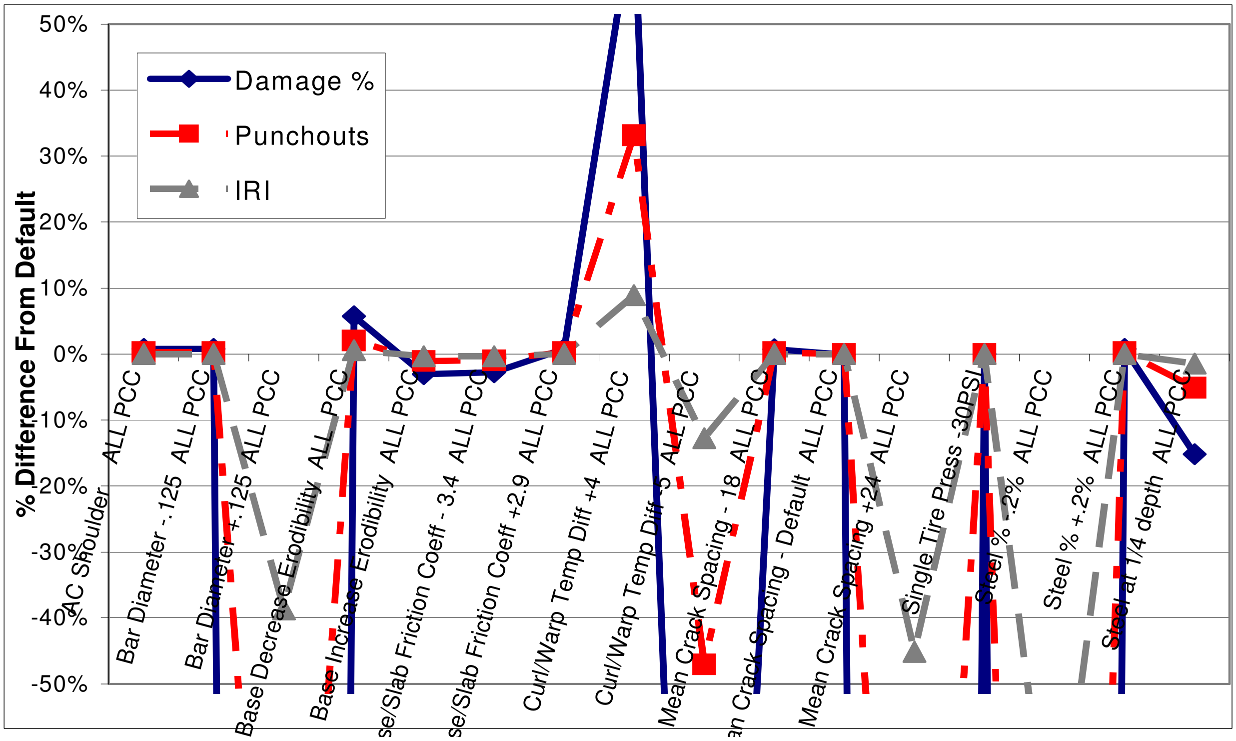

Figure M-4. Dry-Cold, CRCP Bonded Overlay, CRCP Design Variables.

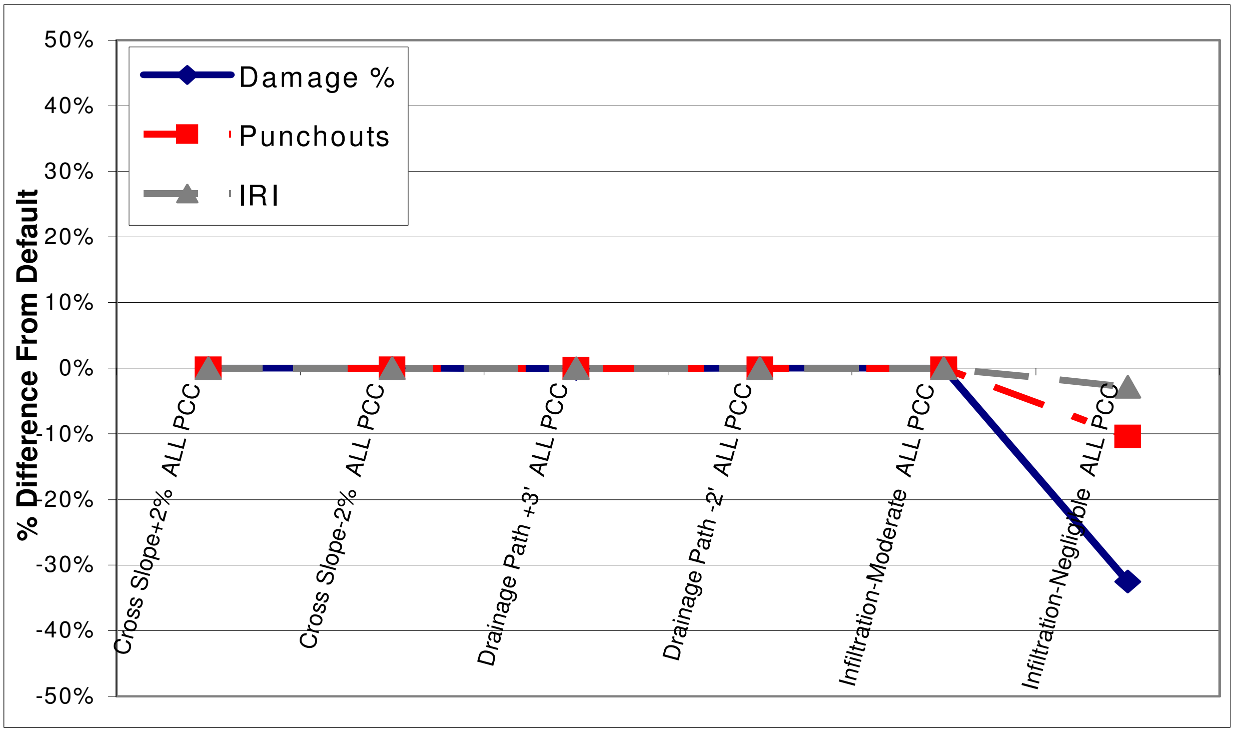

Figure M-5. Dry-Cold, CRCP Bonded Overlay, Drainage Variables.

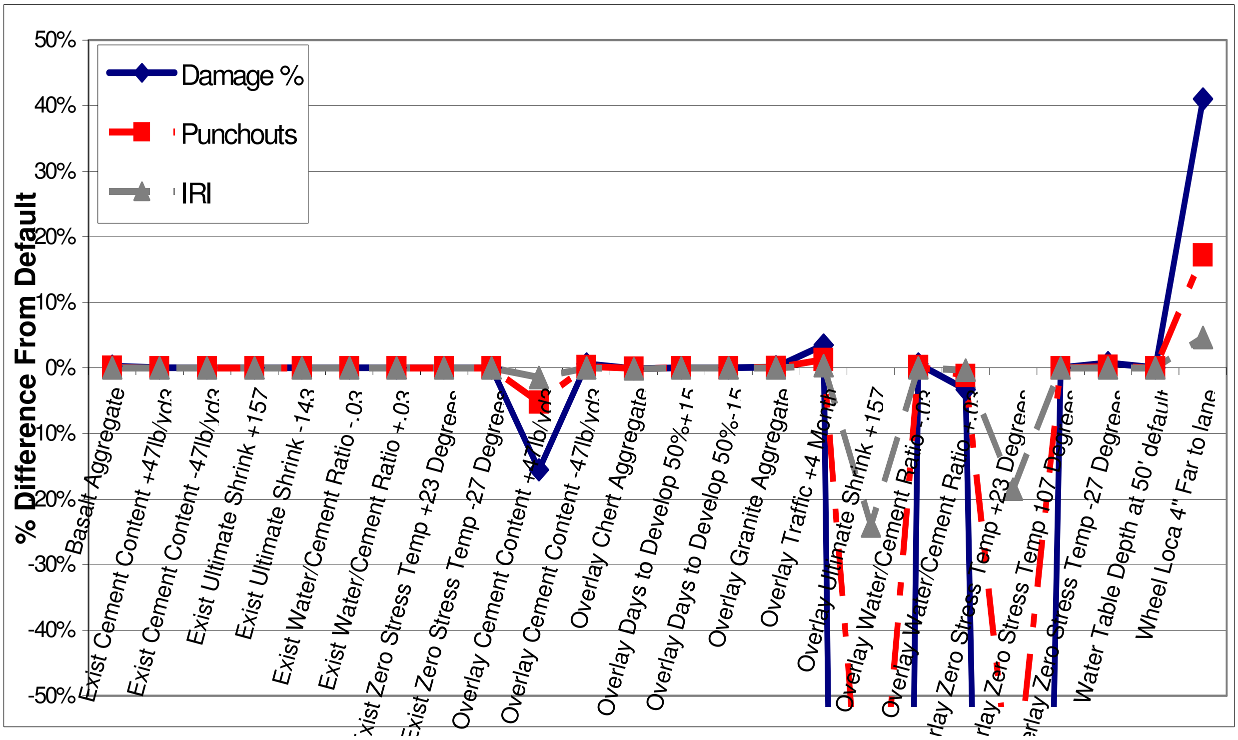

Figure M-6. Dry-Cold, CRCP Bonded Overlay, CRCP Mix Variables.

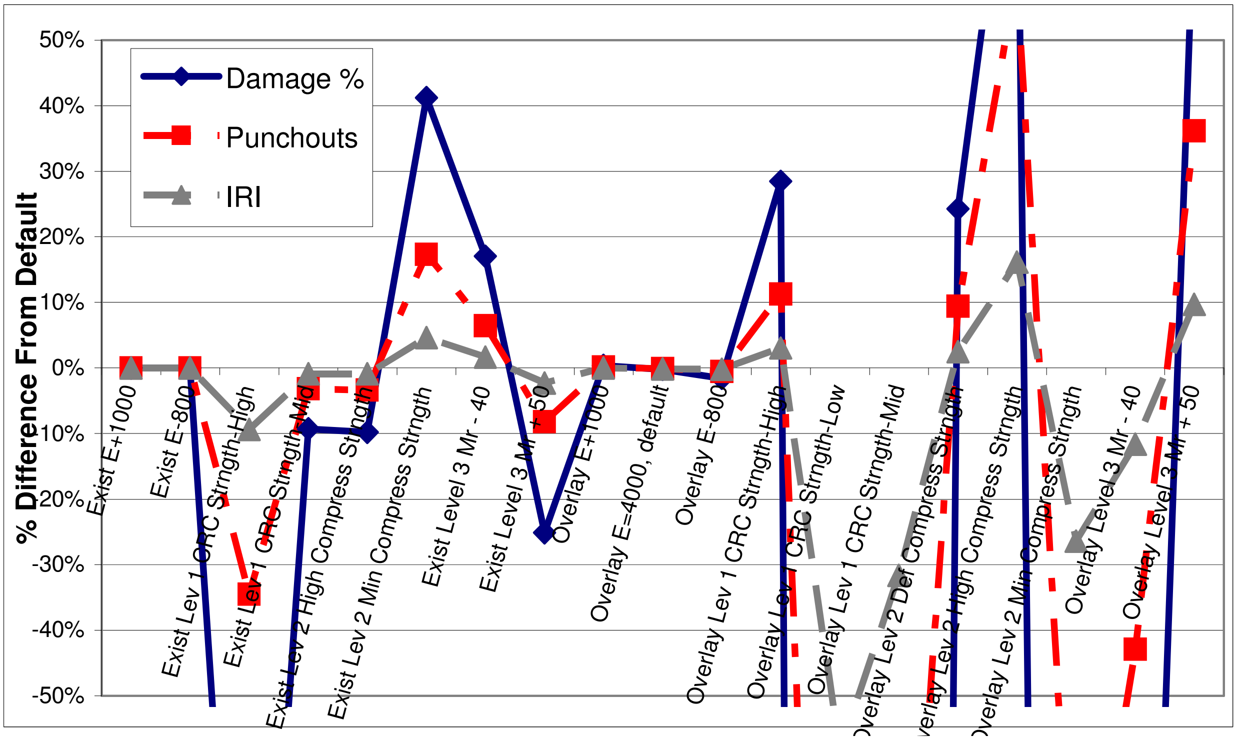

Figure M-7. Dry-Cold, CRCP Bonded Overlay, CRCP Strength Variables.

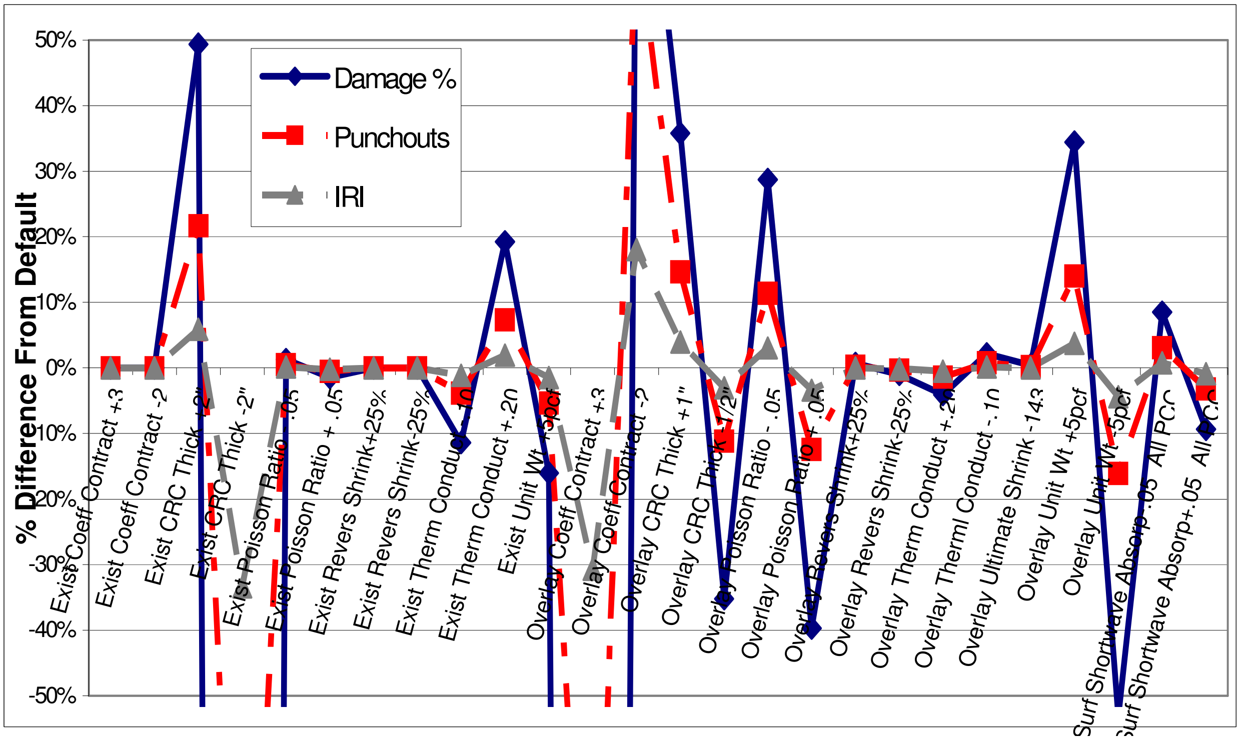

Figure M-8. Dry-Cold, CRCP Bonded Overlay, CRCP Thermal Variables.

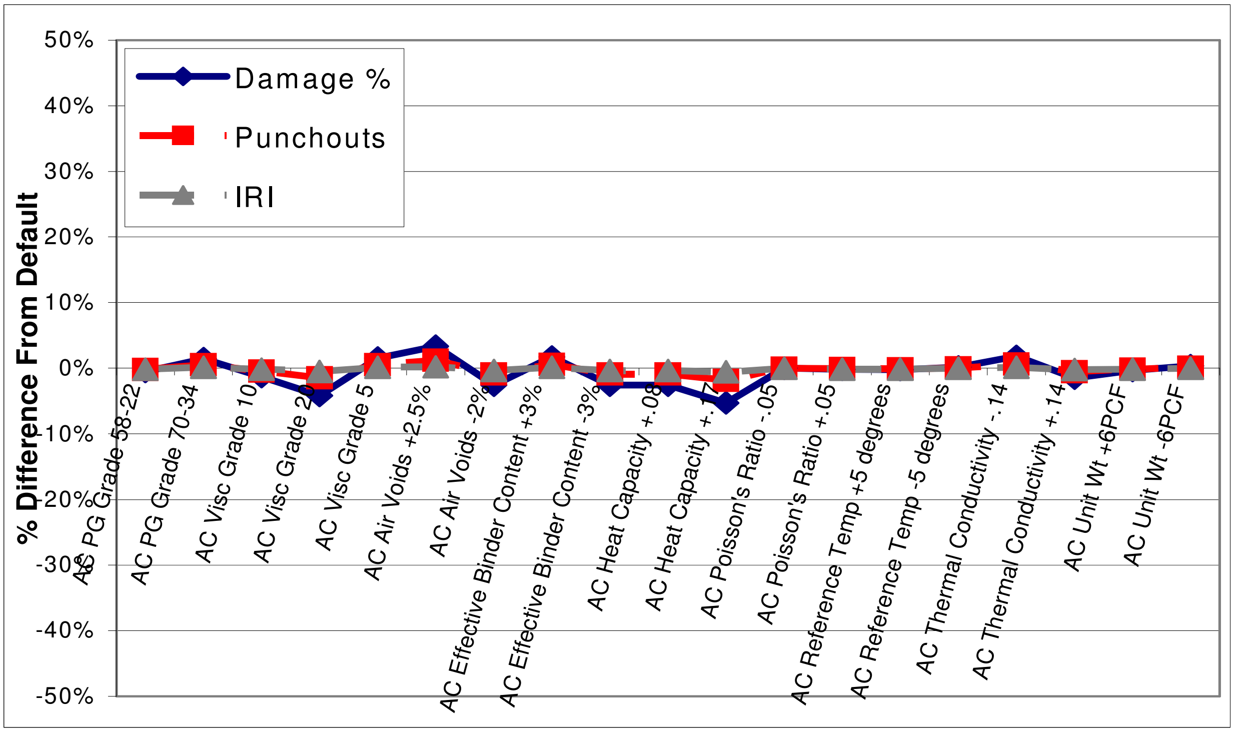

Figure M-9. Dry-Cold, CRCP Bonded Overlay, AC Layer Variables.

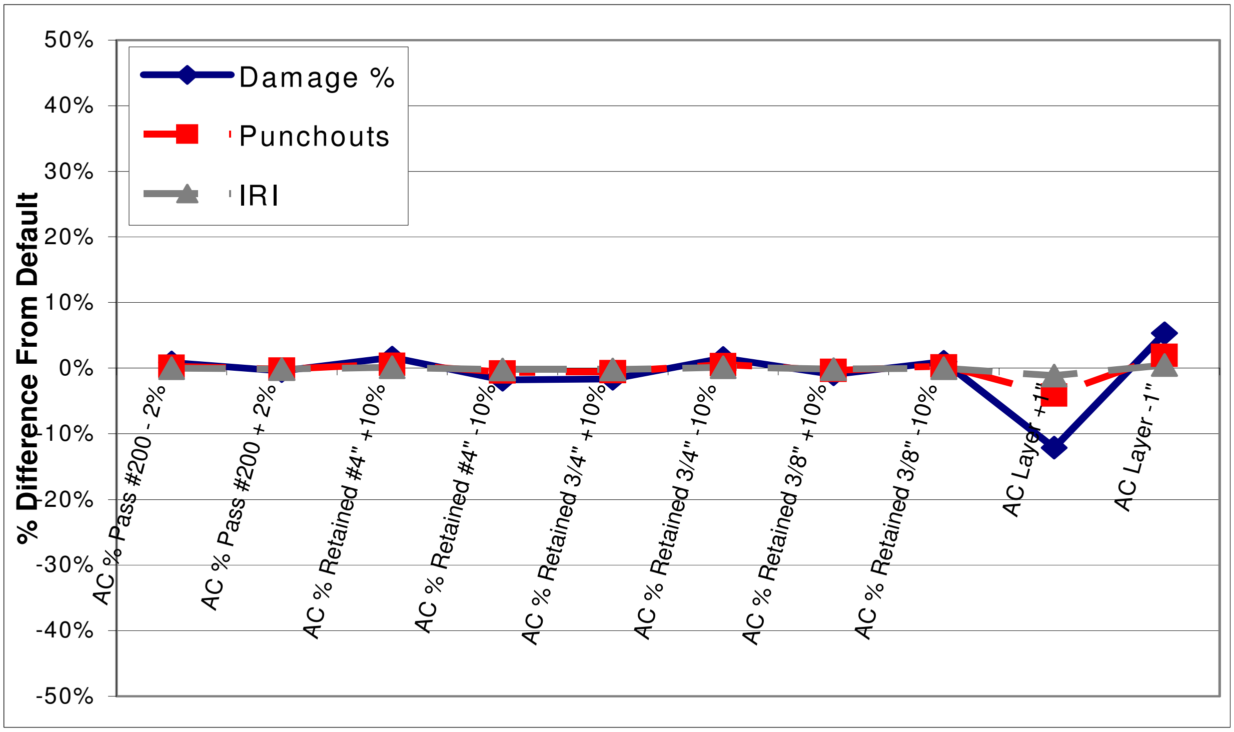

Figure M-10. Dry-Cold, CRCP Bonded Overlay, AC Mix Variables.

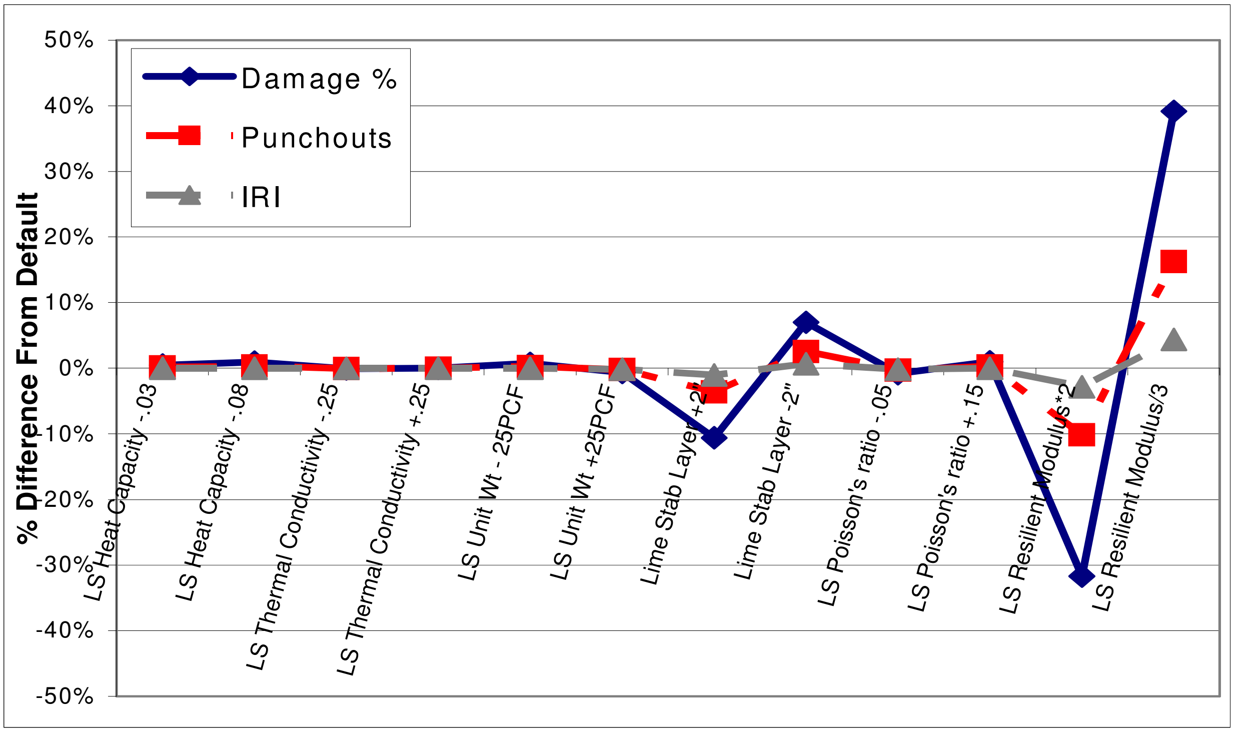

Figure M-11. Dry-Cold, CRCP Bonded Overlay, Lime Modified Layer Variables.

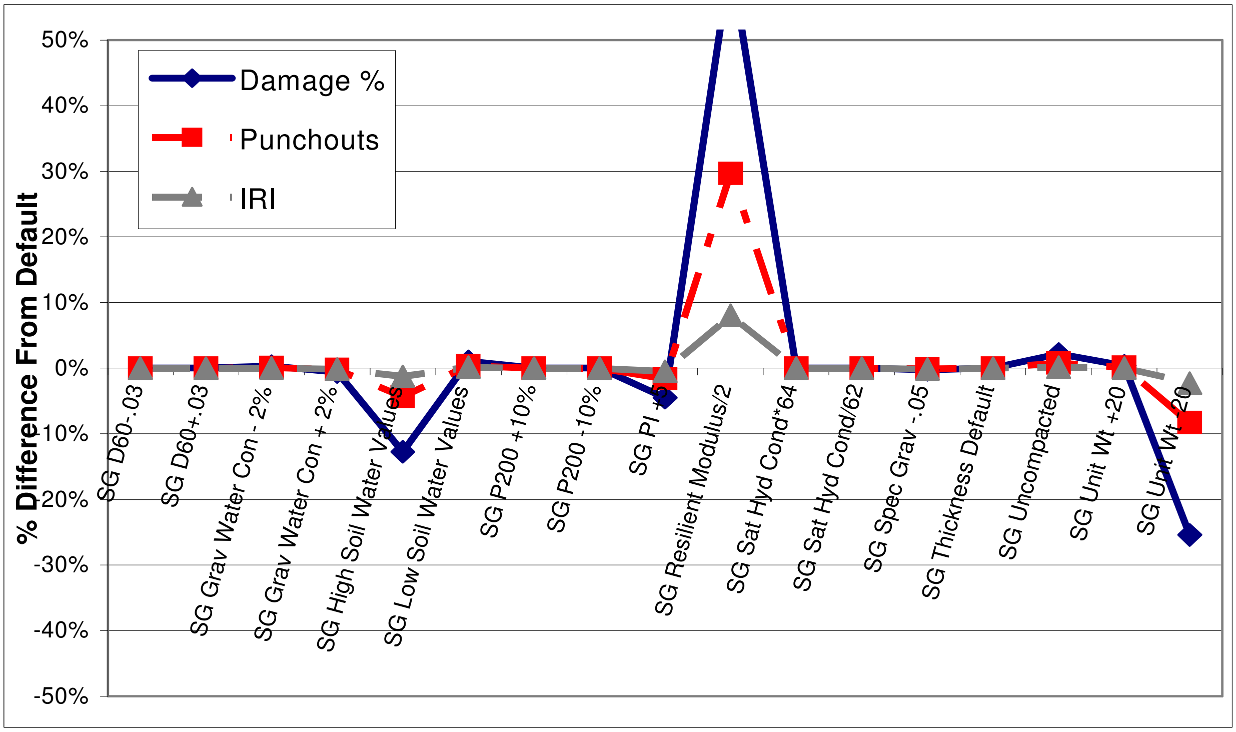

Figure M-12. Dry-Cold, CRCP Bonded Overlay, Subgrade ICM Variables.

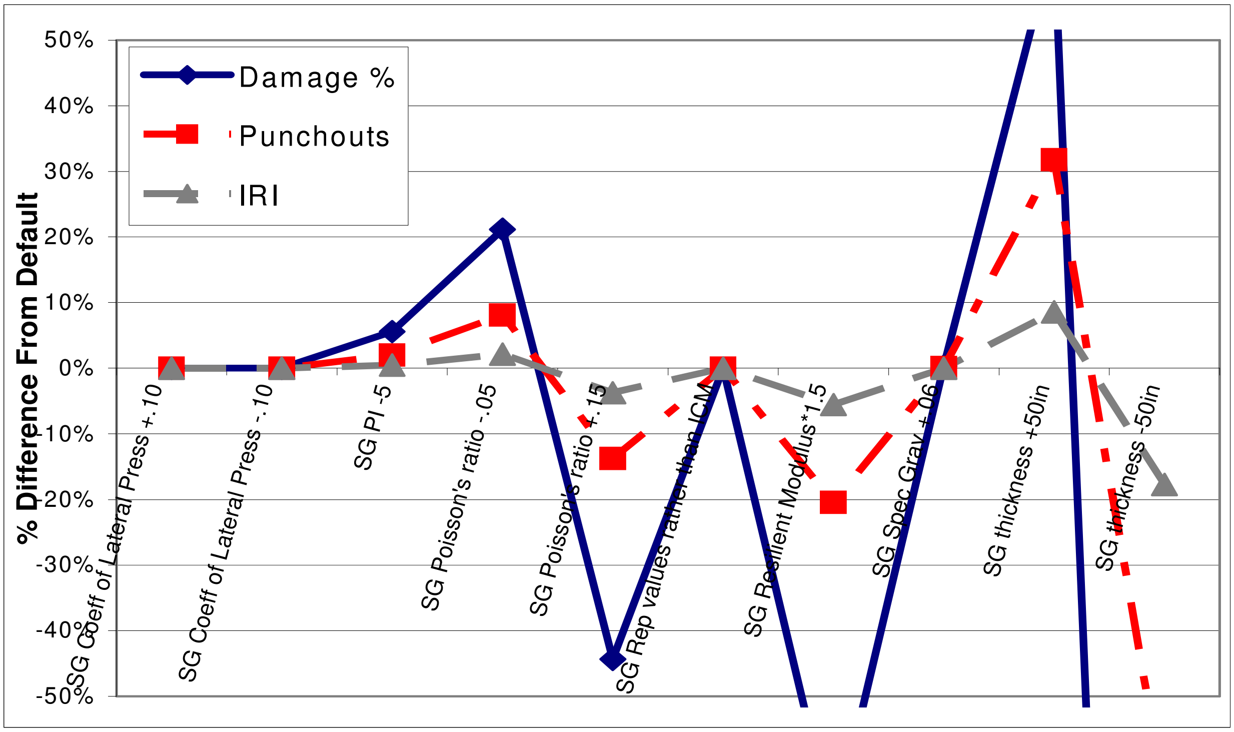

Figure M-13. Dry-Cold, CRCP Bonded Overlay, Subgrade Strength Variables.

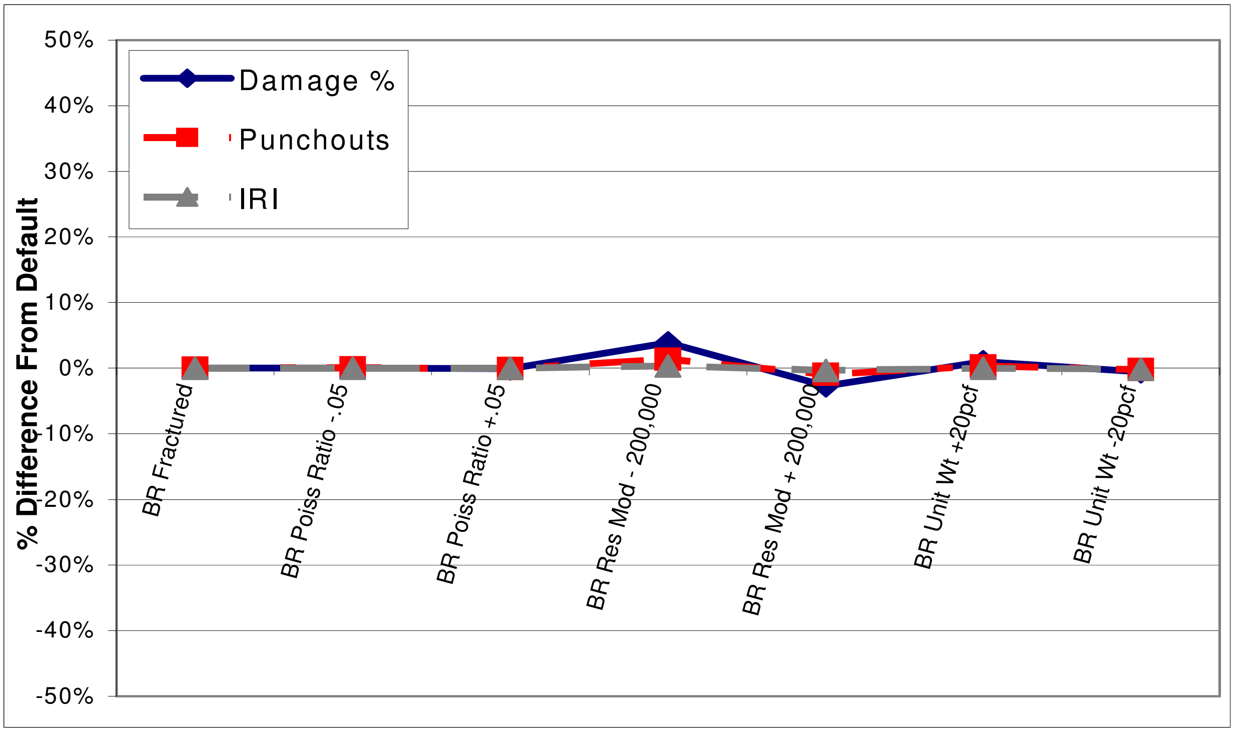

Figure M-14. Dry-Cold, CRCP Bonded Overlay, Bedrock Variables.

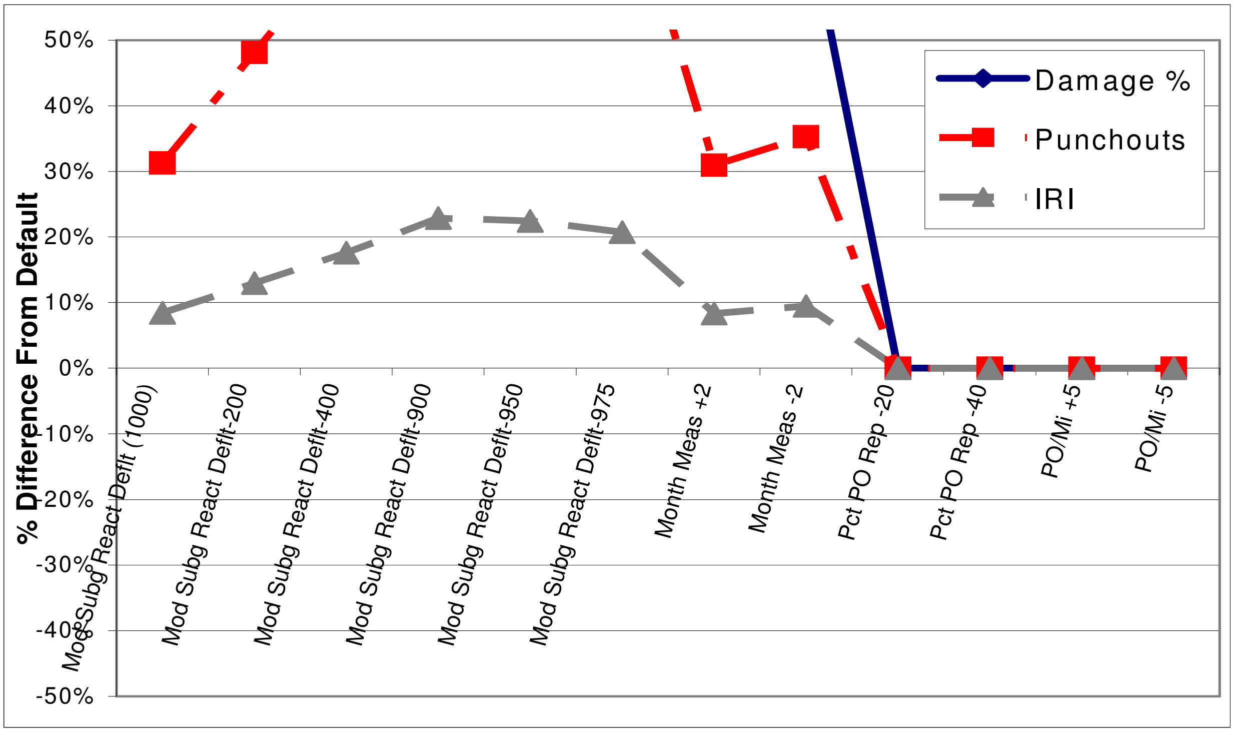

Figure M-15. Dry-Cold, CRCP Bonded Overlay, Rehabilitation Variables.

Table M-7. Results of Dry-Cold, CRCP Bonded Overlay, General Variables.

Description	Category	Damage %	Punchouts	IRI
Overlay Construct −5 Month	01-General	<	<	<
Overlay Construct +2 Month	01-General	<	<	<
Overlay Construct +4 Month	01-General	<	<	<
Overlay Traffic +4 Month	01-General	>	>	>
Local Road TTC Class 9	02-Site	=	=	=
Minor Arterial TTC Class 4	02-Site	=	=	=

Table M-8. Results of Dry-Cold, CRCP Bonded Overlay, Traffic Variables.

Description	Category	Damage %	Punchouts	IRI
AADT −1600 (20%)	03-Traffic	> >	> >	> >
AADT +1600 (20%)	03-Traffic	< <	< <	< <
Exist Unit Wt −5pcf	03-Traffic-General	> >	> >	> >
Lane Width 2' Less	03-Traffic-General	=	=	=
Lane Width 2' More	03-Traffic-General	=	=	=
Wander 2" Less	03-Traffic-General	> >	> >	> >
Wheel Loca 4" Close to Lane	03-Traffic-General	< < <	< < <	< < <
ALL Tire Press +30PSI	03-Traffic-General-Axle	=	=	=
ALL Tire Press −30PSI	03-Traffic-General-Axle	=	=	=
Dual Tire Press +30PSI	03-Traffic-General-Axle	=	=	=
Dual Tire Press −30PSI	03-Traffic-General-Axle	=	=	=
Single Tire Press +30PSI	03-Traffic-General-Axle	=	=	=

Table M-9. Results of Dry-Cold, CRCP Bonded Overlay, Climate Variables.

Description	Category	Damage %	Punchouts	IRI
Elevation −1500'	04-Climate	<	<	< <
Elevation +1500'	04-Climate	>	>	> >
Latitude −0.8	04-Climate	<	<	<
Latitude +1.0	04-Climate	<	<	< <
Longitude +1.0	04-Climate	>	>	<
Longitude −1.0	04-Climate	>	>	<
Steel at 2" Depth All PCC	04-Climate	>	>	=
Wander 2" More	04-Climate	< <	< <	< <
Water Table Depth at 1'	04-Climate	> >	> >	> >
Water Table Depth at 100'	04-Climate	> >	> >	> >

Table M-10. Results of Dry-Cold, CRCP Bonded Overlay, DesignVariables.

Description	Category	Damage %	Punchouts	IRI
AC Shoulder All PCC	06-Design	>	>	=
Bar Diameter −0.125 All PCC	06-Design	>	>	=
Bar Diameter +0.125 All PCC	06-Design	< < <	< < <	< < <
Base Decrease Erodibility All PCC	06-Design	>	>	>
Base Increase Erodibility All PCC	06-Design	<	<	<
Base/Slab Friction Coeff −3.4 All PCC	06-Design	<	<	<
Base/Slab Friction Coeff +2.9 All PCC	06-Design	>	>	=
Curl/Warp Temp Diff +4 All PCC	06-Design	> > >	> > >	> > >
Curl/Warp Temp Diff −5 All PCC	06-Design	< < <	< < <	< < <
Mean Crack Spacing −18 All PCC	06-Design	>	>	=
Mean Crack Spacing - Default All PCC	06-Design	=	=	=
Mean Crack Spacing +24 All PCC	06-Design	< < <	< < <	< < <
Single Tire Press −30PSI	06-Design	=	=	=
Steel % −0.2% All PCC	06-Design	< < <	< < <	< < <
Steel % +0.2% All PCC	06-Design	>	>	=
Steel at 1/4 Depth All PCC	06-Design	< <	< <	< <

Table M-11. Results of Dry-Cold, CRCP Bonded Overlay, Drainage Variables.

Description	Category	Damage %	Punchouts	IRI
Cross Slope +2% All PCC	07-Drain	=	=	=
Cross Slope −2% All PCC	07-Drain	=	=	=
Drainage Path +3' All PCC	07-Drain	=	=	=
Drainage Path −2' All PCC	07-Drain	=	=	=
Infiltration-Moderate All PCC	07-Drain	=	=	=
Infiltration-Negligible All PCC	07-Drain	< <	< <	< <

Table M-12. Results of Dry-Cold, CRCP Bonded Overlay, Mix Variables.

Description	Category	Damage %	Punchouts	IRI
Basalt Aggregate	08-CRC-Mix	>	=	=
Exist Cement Content +47lb/yd3	08-CRC-Mix	=	=	=
Exist Cement Content −47lb/yd3	08-CRC-Mix	=	=	=
Exist Ultimate Shrink +157	08-CRC-Mix	=	=	=
Exist Ultimate Shrink −143	08-CRC-Mix	=	=	=
Exist Water/Cement Ratio −0.03	08-CRC-Mix	=	=	=
Exist Water/Cement Ratio +0.03	08-CRC-Mix	=	=	=
Exist Zero Stress Temp +23 Degrees	08-CRC-Mix	=	=	=
Exist Zero Stress Temp −27 Degrees	08-CRC-Mix	=	=	=
Overlay Cement Content +47lb/yd3	08-CRC-Mix	<<	<<	<<
Overlay Cement Content −47lb/yd3	08-CRC-Mix	>	>	=
Overlay Chert Aggregate	08-CRC-Mix	<	=	<
Overlay Days to Develop 50% +15	08-CRC-Mix	=	=	=
Overlay Days to Develop 50% −15	08-CRC-Mix	=	=	=
Overlay Granite Aggregate	08-CRC-Mix	>	=	=
Overlay Ultimate Shrink +157	08-CRC-Mix	<<<	<<<	<<<
Overlay Water/Cement Ratio −0.03	08-CRC-Mix	>	>	=
Overlay Water/Cement Ratio +0.03	08-CRC-Mix	<	<	<
Overlay Wet Cure	08-CRC-Mix	>	>	=
Overlay Zero Stress Temp +23 Degrees	08-CRC-Mix	<<<	<<<	<<<
Overlay Zero Stress Temp 107 Degrees	08-CRC-Mix	=	=	=
Overlay Zero Stress Temp −27 Degrees	08-CRC-Mix	>	>	=
Water Table Depth at 50' Default	08-CRC-Mix	=	=	=
Wheel Loca 4" Far to Lane	08-CRC-Mix	>>	>>>	>>>

Table M-13. Results of Dry-Cold, CRCP Bonded Overlay, Strength Variables.

Description	Category	Damage %	Punchouts	IRI
Exist E +1000ksi	08-CRC-Strength	=	=	=
Exist E −800ksi	08-CRC-Strength	=	=	=
Exist Lev 1 CRC Strength-High	08-CRC-Strength	< < <	< < <	< < <
Exist Lev 1 CRC Strength-Mid	08-CRC-Strength	< <	<	< <
Exist Lev 2 High Compress Strength	08-CRC-Strength	< <	< <	< <
Exist Lev 2 Min Compress Strength	08-CRC-Strength	> >	> > >	> > >
Exist Level 3 Mr −40psi	08-CRC-Strength	> >	> >	> >
Exist Level 3 Mr +50psi	08-CRC-Strength	< <	< <	< <
Overlay E +1000ksi	08-CRC-Strength	>	>	=
Overlay E =4000ksi, default	08-CRC-Strength	<	=	<
Overlay E −800ksi	08-CRC-Strength	<	<	<
Overlay Lev 1 CRC Strength-High	08-CRC-Strength	> >	> >	> >
Overlay Lev 1 CRC Strength-Low	08-CRC-Strength	< < <	< < <	< < <
Overlay Lev 1 CRC Strength-Mid	08-CRC-Strength	< < <	< < <	< < <
Overlay Lev 2 Def Compress Strength	08-CRC-Strength	> >	> >	> >
Overlay Lev 2 High Compress Strength	08-CRC-Strength	> > >	> > >	> > >
Overlay Lev 2 Min Compress Strngth	08-CRC-Strength	< < <	< < <	< < <
Overlay Level 3 Mr −40psi	08-CRC-Strength	< < <	< < <	< < <
Overlay Level 3 Mr +50psi	08-CRC-Strength	> > >	> > >	> > >

Table M-14. Results of Dry-Cold, CRCP Bonded Overlay, Thermal Variables.

Description	Category	Damage %	Punchouts	IRI
Exist Coeff Contract +3	08-CRC-Thermal	=	=	=
Exist Coeff Contract −2	08-CRC-Thermal	=	=	=
Exist CRC Thick +2"	08-CRC-Thermal	> > >	> > >	> > >
Exist CRC Thick −2"	08-CRC-Thermal	< < <	< < <	< < <
Exist Poisson Ratio −0.05	08-CRC-Thermal	>	>	>
Exist Poisson Ratio +0.05	08-CRC-Thermal	<	<	<
Exist Revers Shrink +25%	08-CRC-Thermal	=	=	=
Exist Revers Shrink −25%	08-CRC-Thermal	=	=	=
Exist Therm Conduct −0.10	08-CRC-Thermal	< <	< <	< <
Exist Therm Conduct +0.20	08-CRC-Thermal	> >	> >	> >
Exist Unit Wt +5pcf	08-CRC-Thermal	< <	< <	< <
Overlay Coeff Contract +3	08-CRC-Thermal	< < <	< < <	< < <
Overlay Coeff Contract −2	08-CRC-Thermal	> > >	> > >	> > >
Overlay CRC Thick +1"	08-CRC-Thermal	> >	> >	> >
Overlay CRC Thick −1/2"	08-CRC-Thermal	< <	< <	< <
Overlay Poisson Ratio −0.05	08-CRC-Thermal	> >	> >	> >
Overlay Poisson Ratio + 0.05	08-CRC-Thermal	< <	< <	< <
Overlay Revers Shrink +25%	08-CRC-Thermal	>	>	=
Overlay Revers Shrink −25%	08-CRC-Thermal	<	<	<
Overlay Therm Conduct +0.20	08-CRC-Thermal	<	<	<
Overlay Therml Conduct −0.10	08-CRC-Thermal	>	>	>
Overlay Ultimate Shrink −143	08-CRC-Thermal	>	>	=
Overlay Unit Wt +5pcf	08-CRC-Thermal	> >	> >	> >
Overlay Unit Wt −5pcf	08-CRC-Thermal	< < <	< <	< <
Surf Shortwave Absorp +0.05 All PCC	08-CRC-Thermal	< <	<	< <
Surf Shortwave Absorp −0.05 All PCC	08-CRC-Thermal	>	>	>

Table M-15. Results of Dry-Cold, CRCP Bonded Overlay, AC Binder Variables.

Description	Category	Damage %	Punchouts	IRI
AC PG Grade 58-22	09-AC-Binder	<	<	<
AC PG Grade 70-34	09-AC-Binder	>	>	>
AC Visc Grade 10	09-AC-Binder	<	<	<
AC Visc Grade 20	09-AC-Binder	<	<	<
AC Visc Grade 5	09-AC-Binder	>	>	>

Table M-16. Results of Dry-Cold, CRCP Bonded Overlay, AC General Variables.

Description	Category	Damage %	Punchouts	IRI
AC Air Voids +2.5%	09-AC-General	>	>	>
AC Air Voids −2%	09-AC-General	<	<	<
AC Effective Binder Content +3%	09-AC-General	>	>	>
AC Effective Binder Content −3%	09-AC-General	<	<	<
AC Heat Capacity +0.08	09-AC-General	<	<	<
AC Heat Capacity +0.17	09-AC-General	<	<	<
AC Poisson's Ratio −0.05	09-AC-General	=	=	=
AC Poisson's Ratio +0.05	09-AC-General	<	=	<
AC Reference Temp +5 degrees	09-AC-General	<	=	<
AC Reference Temp −5 degrees	09-AC-General	>	=	=
AC Thermal Conductivity −0.14	09-AC-General	>	>	>
AC Thermal Conductivity +0.14	09-AC-General	<	<	<
AC Unit Wt +6PCF	09-AC-General	<	<	<
AC Unit Wt −6PCF	09-AC-General	>	>	=

Table M-17. Results of Dry-Cold, CRCP Bonded Overlay, AC Mix Variables.

Description	Category	Damage %	Punchouts	IRI
AC % Pass #200 −2%	09-AC-Mix	>	>	=
AC % Pass #200 +2%	09-AC-Mix	<	<	<
AC % Retained #4 +10%	09-AC-Mix	>	>	>
AC % Retained #4 −10%	09-AC-Mix	<	<	<
AC % Retained 3/4" +10%	09-AC-Mix	<	<	<
AC % Retained 3/4" −10%	09-AC-Mix	>	>	>
AC % Retained 3/8" +10%	09-AC-Mix	<	<	<
AC % Retained 3/8" −10%	09-AC-Mix	>	>	=
AC Layer +1"	09-AC-Mix	<<	<<	<<
AC Layer −1"	09-AC-Mix	>	>	>

Table M-18. Results of Dry-Cold, CRCP Bonded Overlay, Lime Stabilized ICM Variables.

Description	Category	Damage %	Punchouts	IRI
LS Heat Capacity −0.03	10-LS-ICM	>	>	=
LS Heat Capacity −0.08	10-LS-ICM	>	>	=
LS Thermal Conductivity −0.25	10-LS-ICM	<	=	=
LS Thermal Conductivity +0.25	10-LS-ICM	=	=	=
LS Unit Wt −25PCF	10-LS-ICM	>	>	=
LS Unit Wt +25PCF	10-LS-ICM	<	<	<

Table M-19. Results of Dry-Cold, CRCP Bonded Overlay, Lime Modified Strength Variables.

Description	Category	Damage %	Punchouts	IRI
Lime Stab Layer +2"	10-LS-Strength	< <	< <	< <
Lime Stab Layer −2"	10-LS-Strength	>	>	>
LS Poisson's Ratio −0.05	10-LS-Strength	<	<	<
LS Poisson's Ratio +.15	10-LS-Strength	>	>	=
LS Resilient Modulus×2	10-LS-Strength	< <	< <	< <
LS Resilient Modulus/3	10-LS-Strength	> >	> >	> >

Table M-20. Results of Dry-Cold, CRCP Bonded Overlay, Subgrade ICM Variables.

Description	Category	Damage %	Punchouts	IRI
SG D60 −0.03	11-SG-ICM	=	=	=
SG D60 +0.03	11-SG-ICM	=	=	=
SG Grav Water Con −2%	11-SG-ICM	>	>	=
SG Grav Water Con +2%	11-SG-ICM	<	<	<
SG High Soil Water Values	11-SG-ICM	< <	< <	< <
SG Low Soil Water Values	11-SG-ICM	>	>	>
SG P200 +10%	11-SG-ICM	=	=	=
SG P200 −10%	11-SG-ICM	=	=	=
SG PI +5	11-SG-ICM	<	<	<
SG PI −5	11-SG-ICM	>	>	>
SG Sat Hyd Cond×64	11-SG-ICM	=	=	=
SG Sat Hyd Cond/62	11-SG-ICM	=	=	=
SG Spec Grav −0.05	11-SG-ICM	<	=	<
SG Spec Grav +0.06	11-SG-ICM	>	>	=
SG Thickness Default	11-SG-ICM	=	=	=
SG Uncompacted	11-SG-ICM	>	>	>
SG Unit Wt +20pcf	11-SG-ICM	>	>	=
SG Unit Wt −20pcf	11-SG-ICM	< <	< <	< <

Table M-21. Results of Dry-Cold, CRCP Bonded Overlay, Subgrade Strength Variables.

Description	Category	Damage %	Punchouts	IRI
SG Coeff of Lateral Press +0.10	11-SG-Strength	=	=	=
SG Coeff of Lateral Press −0.10	11-SG-Strength	=	=	=
SG Poisson's ratio −0.05	11-SG-Strength	> >	> >	> >
SG Poisson's ratio +0.15	11-SG-Strength	< <	< <	< <
SG Rep values rather than ICM	11-SG-Strength	=	=	=
SG Resilient Modulus×1.5	11-SG-Strength	< < <	< < <	< < <
SG Resilient Modulus/2	11-SG-Strength	> > >	> > >	> > >
SG Thickness +50"	11-SG-Strength	> > >	> > >	> > >
SG Thickness −50"	11-SG-Strength	< < <	< < <	< < <

Table M-22. Results of Dry-Cold, CRCP Bonded Overlay, Bedrock Variables.

Description	Category	Damage %	Punchouts	IRI
BR Fractured	12-BR	=	=	=
BR Poiss Ratio −0.05	12-BR	=	=	=
BR Poiss Ratio +0.05	12-BR	<	=	=
BR Res Mod −200,000	12-BR	>	>	>
BR Res Mod +200,000	12-BR	<	<	<
BR Unit Wt +20pcf	12-BR	>	>	=
BR Unit Wt −20pcf	12-BR	<	<	<

Table M-23. Results of Dry-Cold, CRCP Bonded Overlay, Rehabilitation Variables.

Description	Category	Damage %	Punchouts	IRI
Mod Subg React Deflt 1000	13-Rehabilitation	> > >	> > >	> > >
Mod Subg React Deflt −200	13-Rehabilitation	> > >	> > >	> > >
Mod Subg React Deflt −400	13-Rehabilitation	> > >	> > >	> > >
Mod Subg React Deflt −900	13-Rehabilitation	> > >	> > >	> > >
Mod Subg React Deflt −950	13-Rehabilitation	> > >	> > >	> > >
Mod Subg React Deflt − 975	13-Rehabilitation	> > >	> > >	> > >
Month Meas +2	13-Rehabilitation	> > >	> > >	> > >
Month Meas −2	13-Rehabilitation	> > >	> > >	> > >
Pct PO Rep −20	13-Rehabilitation	=	=	=
Pct PO Rep −40	13-Rehabilitation	=	=	=
PO/Mi +5	13-Rehabilitation	=	=	=
PO/Mi −5	13-Rehabilitation	=	=	=

APPENDIX N

WET-WARM, CRCP BONDED OVERLAY RESULTS

Table N-1. Wet-Warm, CRCP Bonded Overlay, Highly Significant Variables - Damage.

Description	Category	Damage Rank
Wheel Loca 4" Close to Lane	03-Traffic-General	0.4
Wheel Loca 4" Far to Lane	03-Traffic-General	0.5
Water Table Depth at 100'	04-Climate	0.2
Curl/Warp Temp Diff +4 °F All PCC	06-Design	0.3
Curl/Warp Temp Diff -5 °F All PCC	06-Design	0.1
Exist Lev 1 CRC Strength-High	08-CRC-Strength	0.2
Exist Lev 2 Min Compress Strength	08-CRC-Strength	0.4
Overlay Lev 1 CRC Strngth-High	08-CRC-Strength	0.2
Overlay Lev 1 CRC Strngth-Low	08-CRC-Strength	0.4
Overlay Lev 1 CRC Strngth-Mid	08-CRC-Strength	0.2
Overlay Lev 2 High Compress Strngth	08-CRC-Strength	0.2
Overlay Lev 2 Min Compress Strngth	08-CRC-Strength	0.0
Overlay Level 3 Mr −40 psi	08-CRC-Strength	0.1
Overlay Level 3 Mr +50 psi	08-CRC-Strength	0.3
Exist CRC Thick +2"	08-CRC-Thermal	0.4
Exist CRC Thick −2"	08-CRC-Thermal	0.1
Overlay Coeff Contract +3	08-CRC-Thermal	0.0
Overlay Coeff Contract −2	08-CRC-Thermal	0.2
Overlay CRC Thick +1"	08-CRC-Thermal	0.5
Overlay CRC Thick −1/2"	08-CRC-Thermal	0.3
Overlay Poisson Ratio +0.05	08-CRC-Thermal	0.5
Overlay Unit Wt −5 pcf	08-CRC-Thermal	0.3
SG Grav Water Con −10%	11-SG-ICM	0.0
SG P200 +10%	11-SG-ICM	0.0
SG PI +10	11-SG-ICM	0.0
SG Uncompacted	11-SG-ICM	0.0
SG Unit Wt +23 pcf	11-SG-ICM	0.4
SG Unit Wt −17 pcf	11-SG-ICM	0.0
SG Poisson’s Ratio +0.15	11-SG-Strength	0.4
SG Resilient Modulus +3 ksi	11-SG-Strength	0.4
SG Resilient Modulus −3 ksi	11-SG-Strength	0.4
SG Thickness +50"	11-SG-Strength	0.3
SG Thickness −50"	11-SG-Strength	0.0
Mod Subg React Deflt −200 psi/in.	13-Rehabilitation	0.3
Mod Subg React Deflt −400 psi/in.	13-Rehabilitation	0.2
Mod Subg React Deflt −900 psi/in.	13-Rehabilitation	0.2
Mod Subg React Deflt −950 psi/in.	13-Rehabilitation	0.2
Mod Subg React Deflt −975 psi/in.	13-Rehabilitation	0.2

Table N-2. Wet-Warm, CRCP Bonded Overlay, Significant Variables - Damage.

Description	Category	Damage Rank
AADT −1600 (20%	03-Traffic	1.0
AADT +1600 (20%)	03-Traffic	1.0
Exist Unit Wt −5 pcf	03-Traffic-General	1.6
Wander 2" Less	03-Traffic-General	1.0
Latitude −0.9	04-Climate	1.2
Longitude +0.7	04-Climate	1.1
Wander 2" More	04-Climate	1.5
Water Table Depth at 1'	04-Climate	1.2
Exist Lev 1 CRC Strength-Mid	08-CRC-Strength	2.5
Exist Lev 2 High Compress Strength	08-CRC-Strength	0.9
Exist Level 3 Mr −40 psi	08-CRC-Strength	1.3
Exist Level 3 Mr +50 psi	08-CRC-Strength	0.9
Overlay Lev 2 Def Compress Strength	08-CRC-Strength	0.8
Exist Therm Conduct −0.10	08-CRC-Thermal	1.8
Exist Therm Conduct +0.20	08-CRC-Thermal	1.1
Exist Unit Wt +5 pcf	08-CRC-Thermal	1.5
Overlay Poisson Ratio −0.05	08-CRC-Thermal	0.7
Overlay Unit Wt +5 pcf	08-CRC-Thermal	0.5
Surf Shortwave Absorp −0.05 All PCC	08-CRC-Thermal	2.0
Surf Shortwave Absorp +0.05 All PCC	08-CRC-Thermal	1.7
AC Layer +1"	09-AC-Mix	1.3
Lime Stab Layer +2"	10-LS-Strength	1.9
Lime Stab Layer −2"	10-LS-Strength	2.2
LS Resilient Modulus×2	10-LS-Strength	0.5
LS Resilient Modulus/3	10-LS-Strength	0.5
SG Grav Water Con +10%	11-SG-ICM	1.8
SG Poisson's Ratio −0.05	11-SG-Strength	0.8
Mod Subg React Deflt 1000 psi/in.	13-Rehabilitation	0.6
Month Meas +2	13-Rehabilitation	0.6
Month Meas −2	13-Rehabilitation	0.6

Table N-3. Wet-Warm, CRCP Bonded Overlay, Highly Significant Variables - Punchouts.

Description	Category	Punchout Rank
Wheel Loca 4" Close to Lane	03-Traffic-General	0.4
Wheel Loca 4" Far to Lane	03-Traffic-General	0.4
Water Table Depth at 100'	04-Climate	0.3
Curl/Warp Temp Diff +4 °F All PCC	06-Design	0.2
Curl/Warp Temp Diff −5 °F All PCC	06-Design	0.1
Exist Lev 1 CRC Strength-High	08-CRC-Strength	0.3
Exist Lev 2 Min Compress Strength	08-CRC-Strength	0.3
Overlay Lev 1 CRC Strength-High	08-CRC-Strength	0.1
Overlay Lev 1 CRC Strength-Low	08-CRC-Strength	0.3
Overlay Lev 1 CRC Strength-Mid	08-CRC-Strength	0.1
Overlay Lev 2 High Compress Strength	08-CRC-Strength	0.1
Overlay Lev 2 Min Compress Strength	08-CRC-Strength	0.1
Overlay Level 3 Mr −40 psi	08-CRC-Strength	0.2
Overlay Level 3 Mr +50 psi	08-CRC-Strength	0.2
Exist CRC Thick +2"	08-CRC-Thermal	0.3
Exist CRC Thick −2"	08-CRC-Thermal	0.2
Overlay Coeff Contract +3	08-CRC-Thermal	0.1
Overlay Coeff Contract −2	08-CRC-Thermal	0.1
Overlay CRC Thick +1"	08-CRC-Thermal	0.4
Overlay CRC Thick −1/2"	08-CRC-Thermal	0.4
Overlay Unit Wt +5 pcf	08-CRC-Thermal	0.5
Overlay Unit Wt −5 pcf	08-CRC-Thermal	0.4
LS Resilient Modulus/3	10-LS-Strength	0.5
SG Grav Water Con −10%	11-SG-ICM	0.1
SG P200 +10%	11-SG-ICM	0.1
SG PI +10	11-SG-ICM	0.1
SG Uncompacted	11-SG-ICM	0.1
SG Unit Wt +23 pcf	11-SG-ICM	0.5
SG Unit Wt −17 pcf	11-SG-ICM	0.1
SG Poisson’s Ratio +.15	11-SG-Strength	0.4
SG Resilient Modulus +3 ksi	11-SG-Strength	0.5
SG Resilient Modulus −3 ksi	11-SG-Strength	0.3
SG Thickness +50"	11-SG-Strength	0.2
SG Thickness −50"	11-SG-Strength	0.1
Mod Subg React Deflt 1000 psi/in.	13-Rehabilitation	0.5
Mod Subg React Deflt-200 psi/in.	13-Rehabilitation	0.2
Mod Subg React Deflt-400 psi/in.	13-Rehabilitation	0.1

Table N-3. Wet-Warm, CRCP Bonded Overlay, Highly Significant Variables - Punchouts (Continued).

Mod Subg React Deflt-900 psi/in.	13-Rehabilitation	0.1
Mod Subg React Deflt-950 psi/in.	13-Rehabilitation	0.1
Mod Subg React Deflt-975 psi/in.	13-Rehabilitation	0.1
Month Meas +2	13-Rehabilitation	0.5
Month Meas −2	13-Rehabilitation	0.5

Table N-4. Wet-Warm, CRCP Bonded Overlay, Significant Variables - Punchouts.

Description	Category	Punchout Rank
AADT −1600 (20%)	03-Traffic	0.9
AADT +1600 (20%)	03-Traffic	1.1
Exist Unit Wt −5 pcf	03-Traffic-General	1.5
Wander 2" Less	03-Traffic-General	1.0
Latitude −0.9	04-Climate	1.1
Longitude +0.7	04-Climate	1.0
Wander 2" More	04-Climate	1.6
Water Table Depth at 1'	04-Climate	1.1
Exist Lev 2 High Compress Strength	08-CRC-Strength	0.9
Exist Level 3 Mr −40 psi	08-CRC-Strength	1.2
Exist Level 3 Mr +50 psi	08-CRC-Strength	1.0
Overlay Lev 2 Def Compress Strength	08-CRC-Strength	0.7
Exist Therm Conduct −0.10	08-CRC-Thermal	1.8
Exist Therm Conduct +0.20	08-CRC-Thermal	1.1
Exist Unit Wt +5pcf	08-CRC-Thermal	1.5
Overlay Poisson Ratio −0.05	08-CRC-Thermal	0.6
Overlay Poisson Ratio +0.05	08-CRC-Thermal	0.5
Surf Shortwave Absorp −0.05 All PCC	08-CRC-Thermal	1.9
Surf Shortwave Absorp +0.05 All PCC	08-CRC-Thermal	1.8
AC Layer +1"	09-AC-Mix	1.4
Lime Stab Layer +2"	10-LS-Strength	1.9
Lime Stab Layer −2"	10-LS-Strength	2.1
LS Resilient Modulus×2	10-LS-Strength	0.6
SG Grav Water Con +10%	11-SG-ICM	1.9
SG Poisson's Ratio −0.05	11-SG-Strength	0.7

Table N-5. Wet-Warm, CRCP Bonded Overlay, Highly Significant Variables - IRI.

Description	Category	IRI Rank
Wheel Loca 4" Close to Lane	03-Traffic-General	0.4
Wheel Loca 4" Far to Lane	03-Traffic-General	0.4
Water Table Depth at 100'	04-Climate	0.2
Curl/Warp Temp Diff +4 °F All PCC	06-Design	0.2
Curl/Warp Temp Diff −5 °F All PCC	06-Design	0.1
Exist Lev 1 CRC Strength-High	08-CRC-Strength	0.3
Exist Lev 2 Min Compress Strength	08-CRC-Strength	0.4
Overlay Lev 1 CRC Strength-High	08-CRC-Strength	0.1
Overlay Lev 1 CRC Strength-Low	08-CRC-Strength	0.3
Overlay Lev 1 CRC Strength-Mid	08-CRC-Strength	0.1
Overlay Lev 2 High Compress Strength	08-CRC-Strength	0.1
Overlay Lev 2 Min Compress Strength	08-CRC-Strength	0.1
Overlay Level 3 Mr −40 psi	08-CRC-Strength	0.2
Overlay Level 3 Mr +50 psi	08-CRC-Strength	0.2
Exist CRC Thick +2"	08-CRC-Thermal	0.3
Exist CRC Thick −2"	08-CRC-Thermal	0.2
Overlay Coeff Contract +3	08-CRC-Thermal	0.1
Overlay Coeff Contract −2	08-CRC-Thermal	0.1
Overlay CRC Thick +1"	08-CRC-Thermal	0.4
Overlay CRC Thick −1/2"	08-CRC-Thermal	0.4
Overlay Unit Wt +5 pcf	08-CRC-Thermal	0.5
Overlay Unit Wt −5 pcf	08-CRC-Thermal	0.4
LS Resilient Modulus/3	10-LS-Strength	0.5
SG Grav Water Con −10%	11-SG-ICM	0.1
SG P200 +10%	11-SG-ICM	0.1
SG PI +10	11-SG-ICM	0.1
SG Uncompacted	11-SG-ICM	0.1
SG Unit Wt +23 pcf	11-SG-ICM	0.5
SG Unit Wt −17 pcf	11-SG-ICM	0.1
SG Poisson’s Ratio +0.15	11-SG-Strength	0.4
SG Resilient Modulus +3 ksi	11-SG-Strength	0.5
SG Resilient Modulus −3 ksi	11-SG-Strength	0.4
SG Thickness +50"	11-SG-Strength	0.2
SG Thickness −50"	11-SG-Strength	0.1
Mod Subg React Deflt −200 psi/in.	13-Rehabilitation	0.2
Mod Subg React Deflt −400 psi/in.	13-Rehabilitation	0.1
Mod Subg React Deflt −900 psi/in.	13-Rehabilitation	0.1

Table N-5. Wet-Warm, CRCP Bonded Overlay, Highly Significant Variables - IRI (Continued).

Mod Subg React Deflt −950 psi/in.	13-Rehabilitation	0.1
Mod Subg React Deflt −975 psi/in.	13-Rehabilitation	0.1
Month Meas −2	13-Rehabilitation	0.5

Table N-6. Wet-Warm, CRCP Bonded Overlay, Significant Variables - IRI.

Description	Category	IRI Rank
AADT −1600	03-Traffic	1.0
AADT +1600	03-Traffic	1.0
Exist Unit Wt −5 pcf	03-Traffic-General	1.4
Wander 2" Less	03-Traffic-General	1.0
Latitude −0.9	04-Climate	1.1
Longitude +0.7	04-Climate	1.0
Wander 2" More	04-Climate	1.6
Water Table Depth at 1'	04-Climate	1.1
Exist Lev 2 High Compress Strength	08-CRC-Strength	1.0
Exist Level 3 Mr −40 psi	08-CRC-Strength	1.3
Exist Level 3 Mr +50 psi	08-CRC-Strength	1.0
Overlay Lev 2 Def Compress Strength	08-CRC-Strength	0.7
Exist Therm Conduct −0.10	08-CRC-Thermal	1.8
Exist Therm Conduct +0.20	08-CRC-Thermal	1.0
Exist Unit Wt +5pcf	08-CRC-Thermal	1.6
Overlay Poisson Ratio −0.05	08-CRC-Thermal	0.6
Overlay Poisson Ratio +0.05	08-CRC-Thermal	0.6
Surf Shortwave Absorp −0.05 All PCC	08-CRC-Thermal	1.8
Surf Shortwave Absorp +0.05 All PCC	08-CRC-Thermal	1.8
AC Layer +1"	09-AC-Mix	1.4
Lime Stab Layer +2"	10-LS-Strength	1.8
Lime Stab Layer -2"	10-LS-Strength	2.1
LS Resilient Modulus×2	10-LS-Strength	0.6
SG Grav Water Con +10%	11-SG-ICM	1.8
SG Poisson's Ratio −0.05	11-SG-Strength	0.7
Mod Subg React Deflt 1000 psi/in.	13-Rehabilitation	0.5
Month Meas +2	13-Rehabilitation	0.5

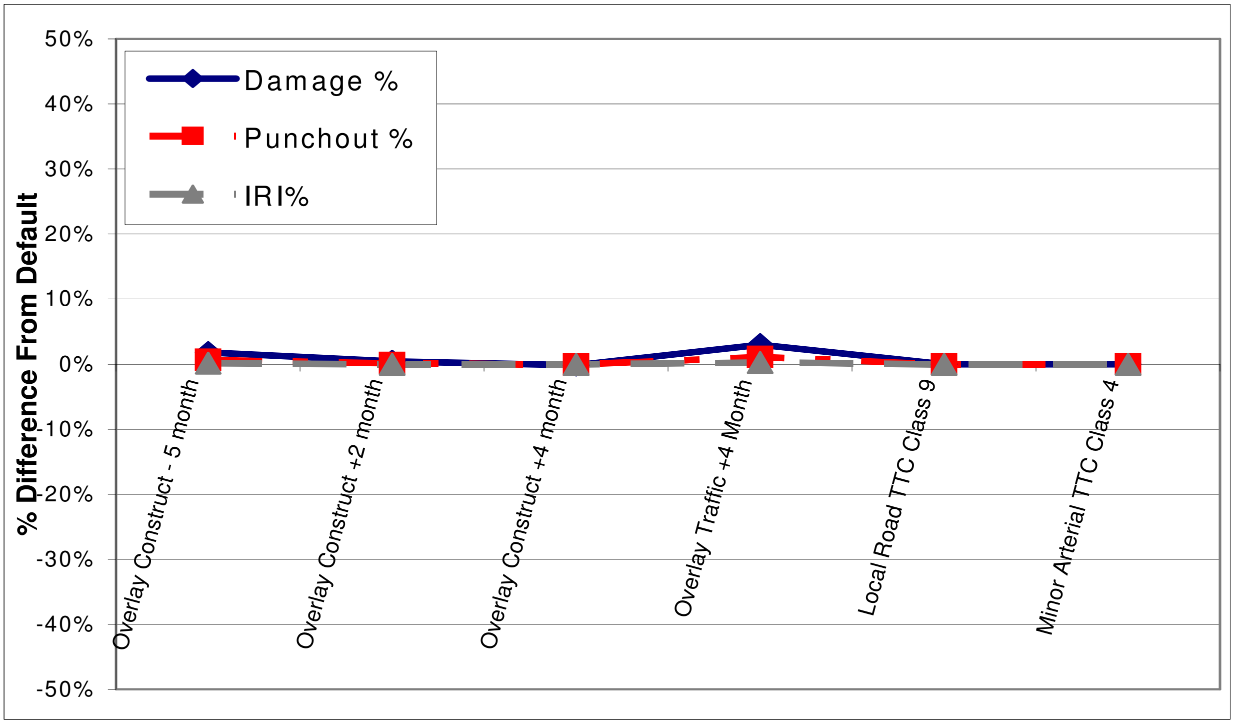

Figure N - 1. Wet-Warm, CRCP Bonded Overlay, General Variables.

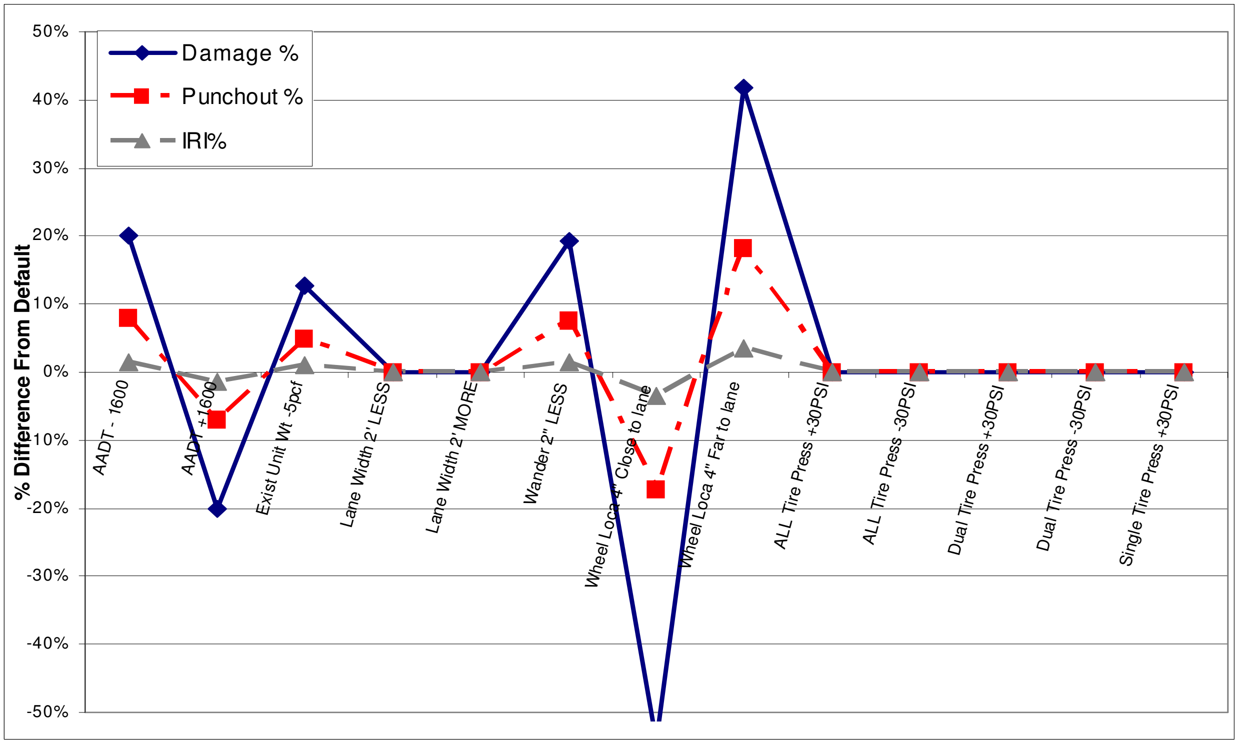

Figure N - 2. Wet-Warm, CRCP Bonded Overlay, Traffic Variables.

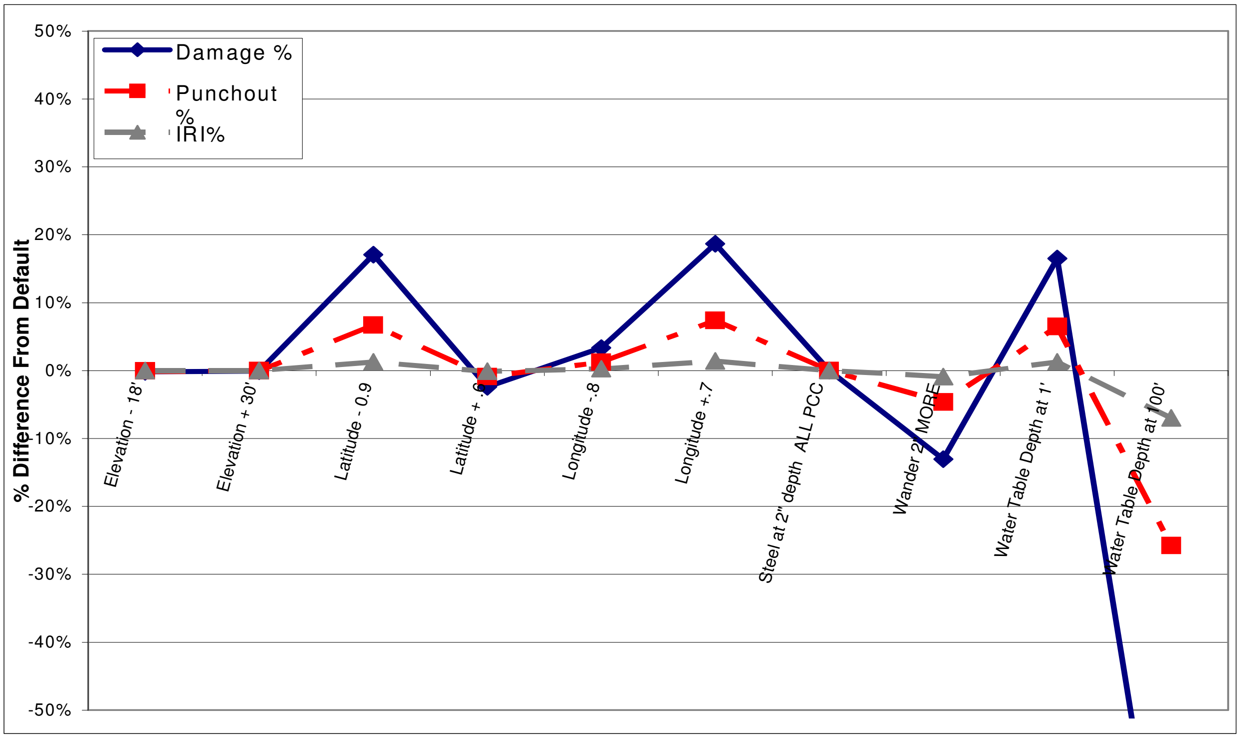

Figure N - 3. Wet-Warm, CRCP Bonded Overlay, Climate Variables.

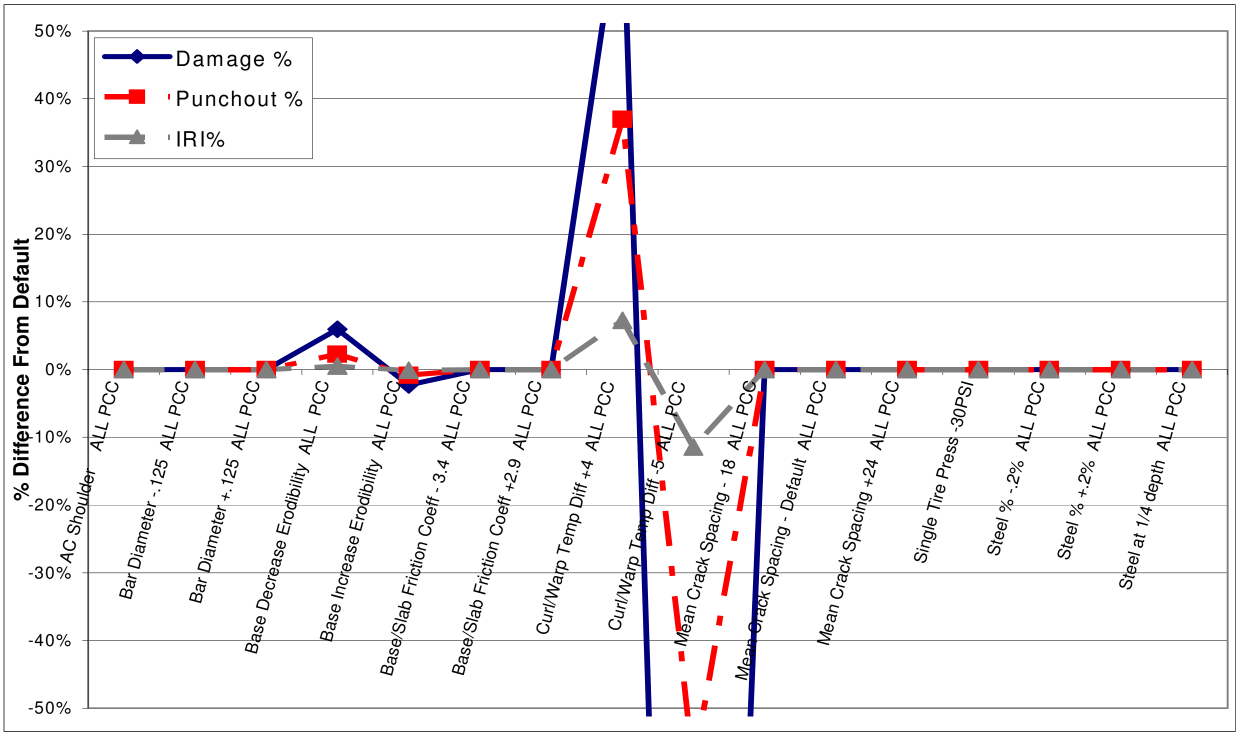

Figure N - 4. Wet-Warm, CRCP Bonded Overlay, CRCP Design Variables.

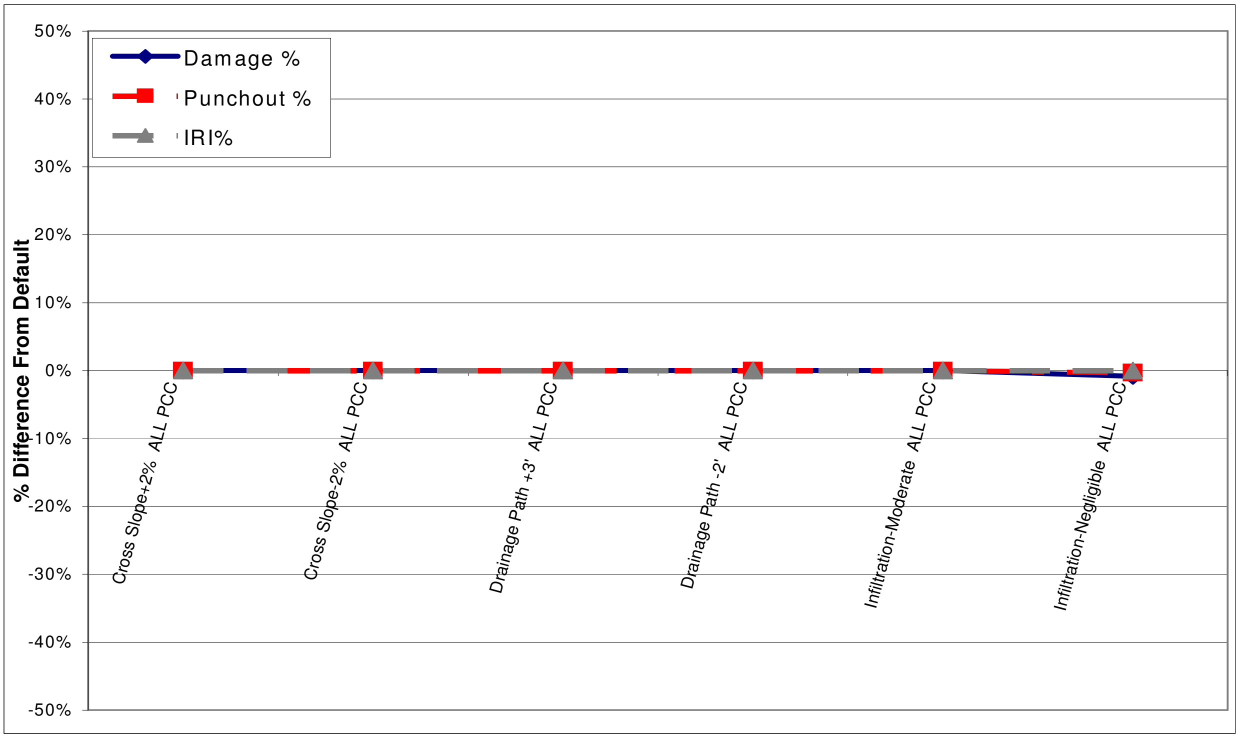

Figure N - 5. Wet-Warm, CRCP Bonded Overlay, Drainage Variables.

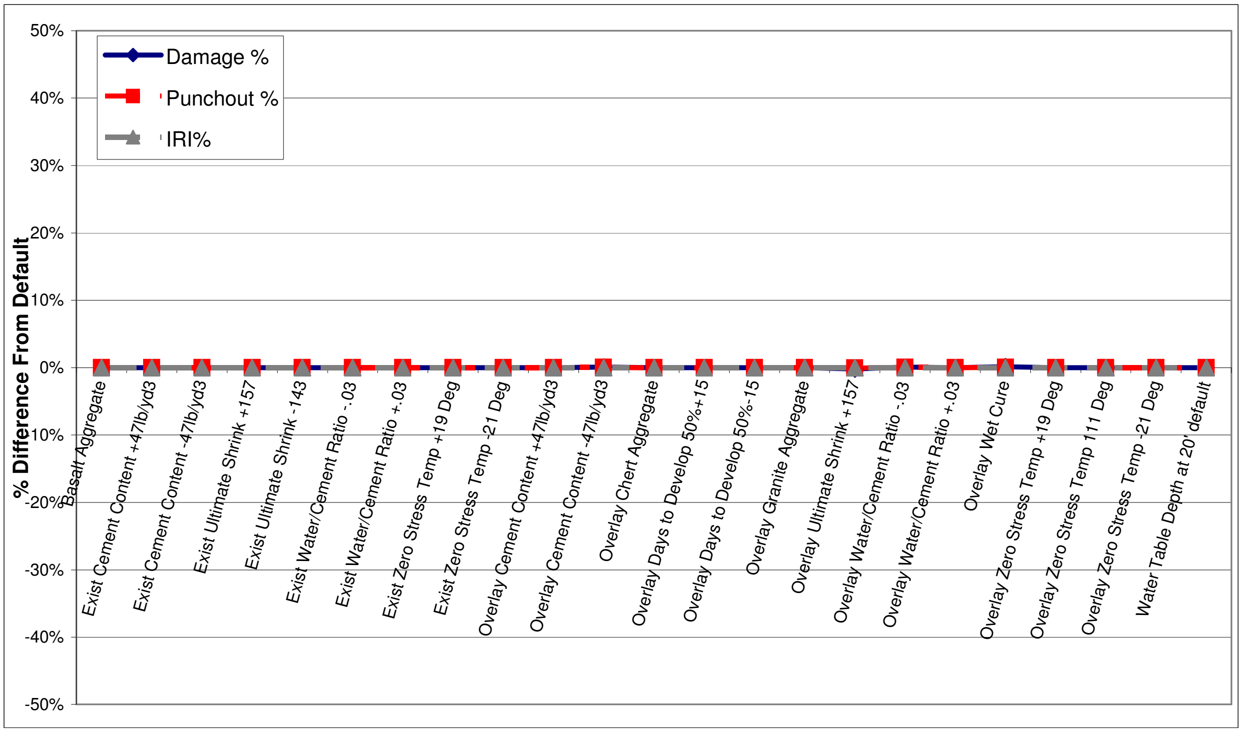

Figure N - 6. Wet-Warm, CRCP Bonded Overlay, CRCP Mix Variables.

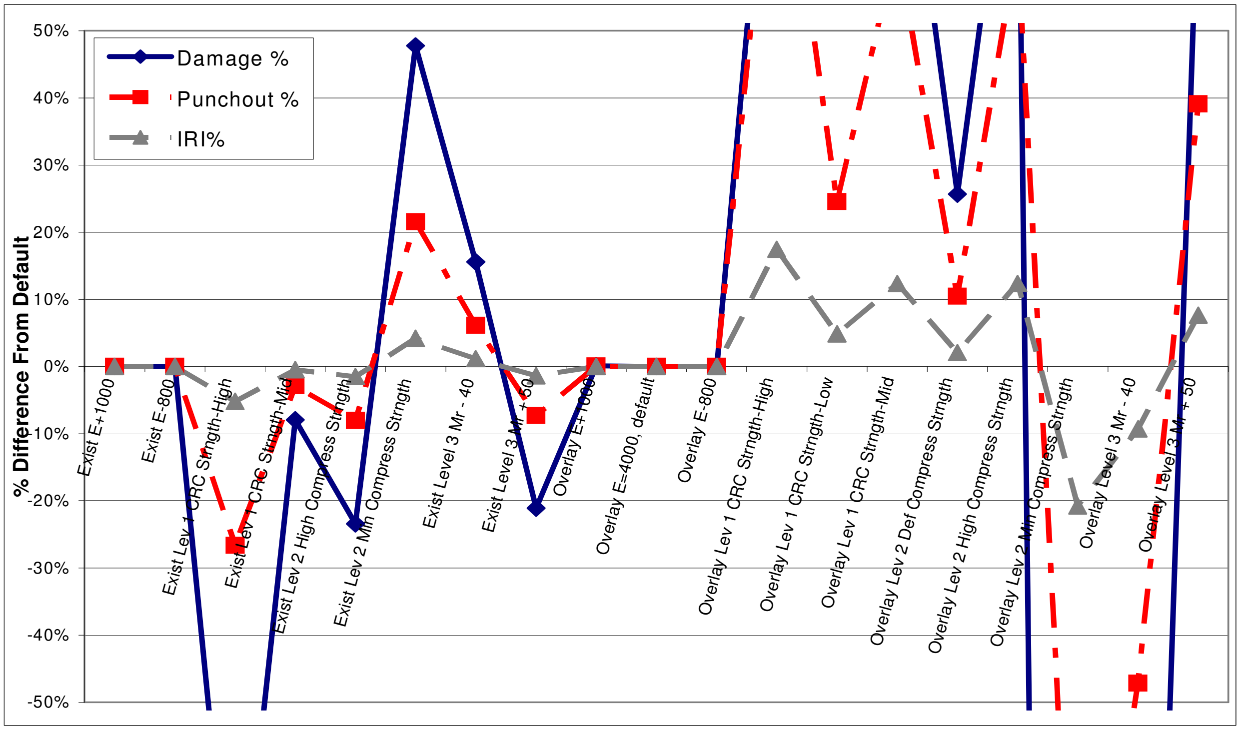

Figure N - 7. Wet-Warm, CRCP Bonded Overlay, CRCP Strength Variables.

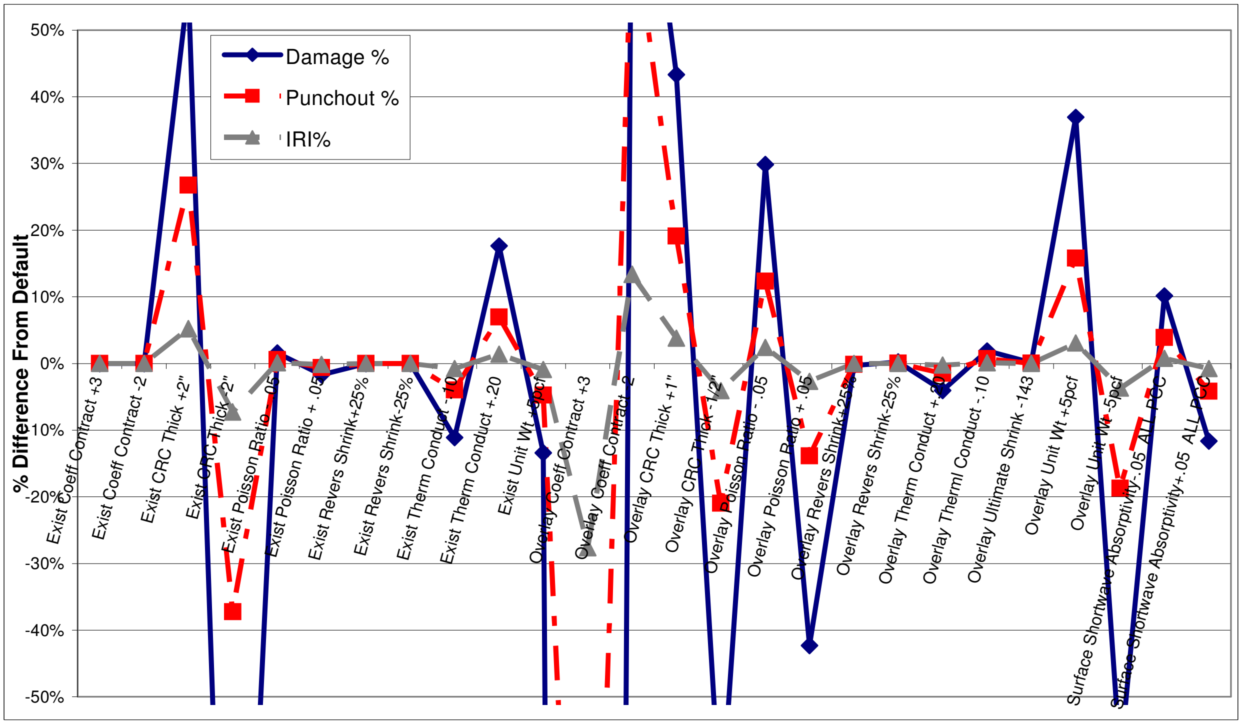

Figure N - 8. Wet-Warm, CRCP Bonded Overlay, CRCP Thermal Variables.

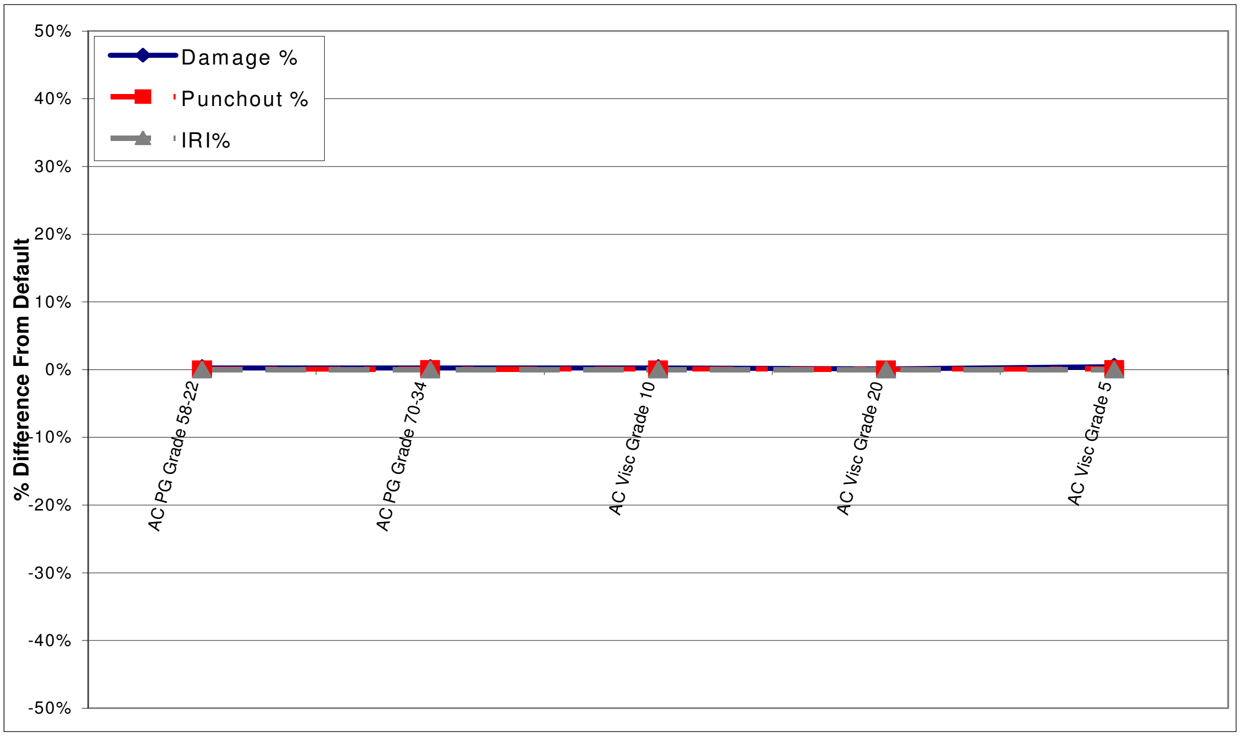

Figure N - 9. Wet-Warm, CRCP Bonded Overlay, AC Binder Variables.

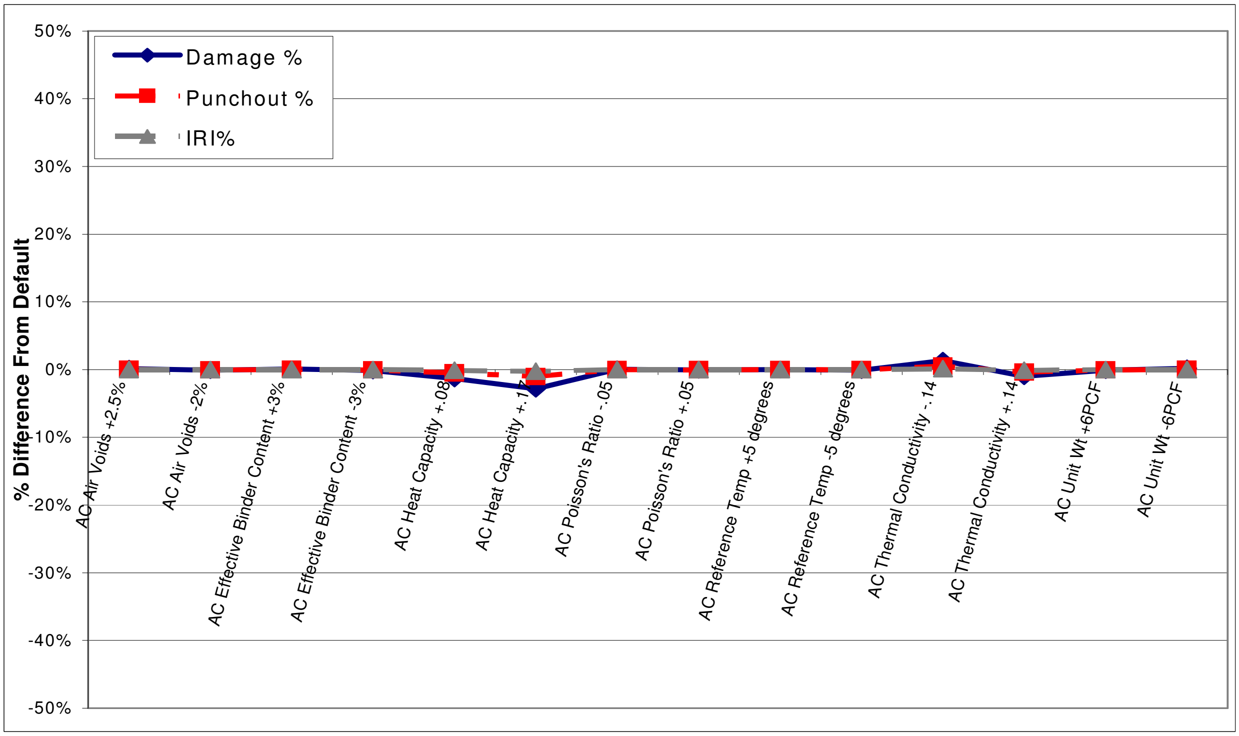

Figure N - 10. Wet-Warm, CRCP Bonded Overlay, AC General Variables.

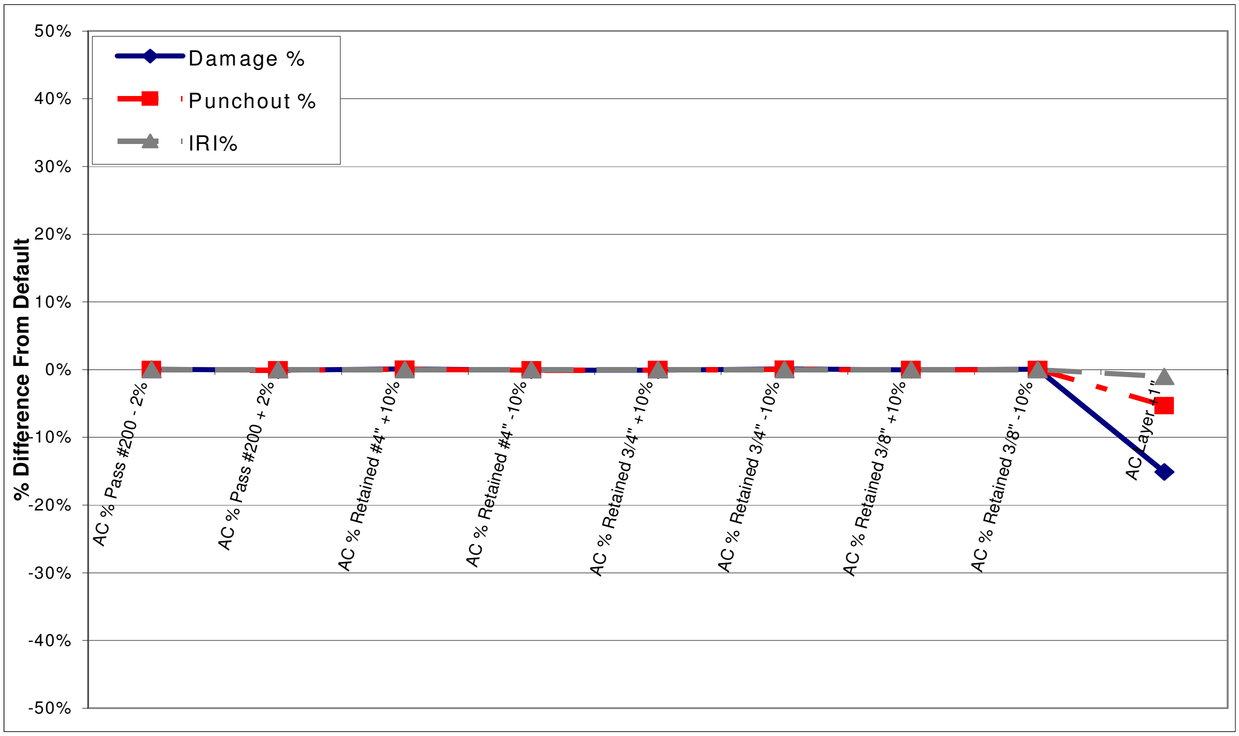

Figure N - 11. Wet-Warm, CRCP Bonded Overlay, AC Mix Variables.

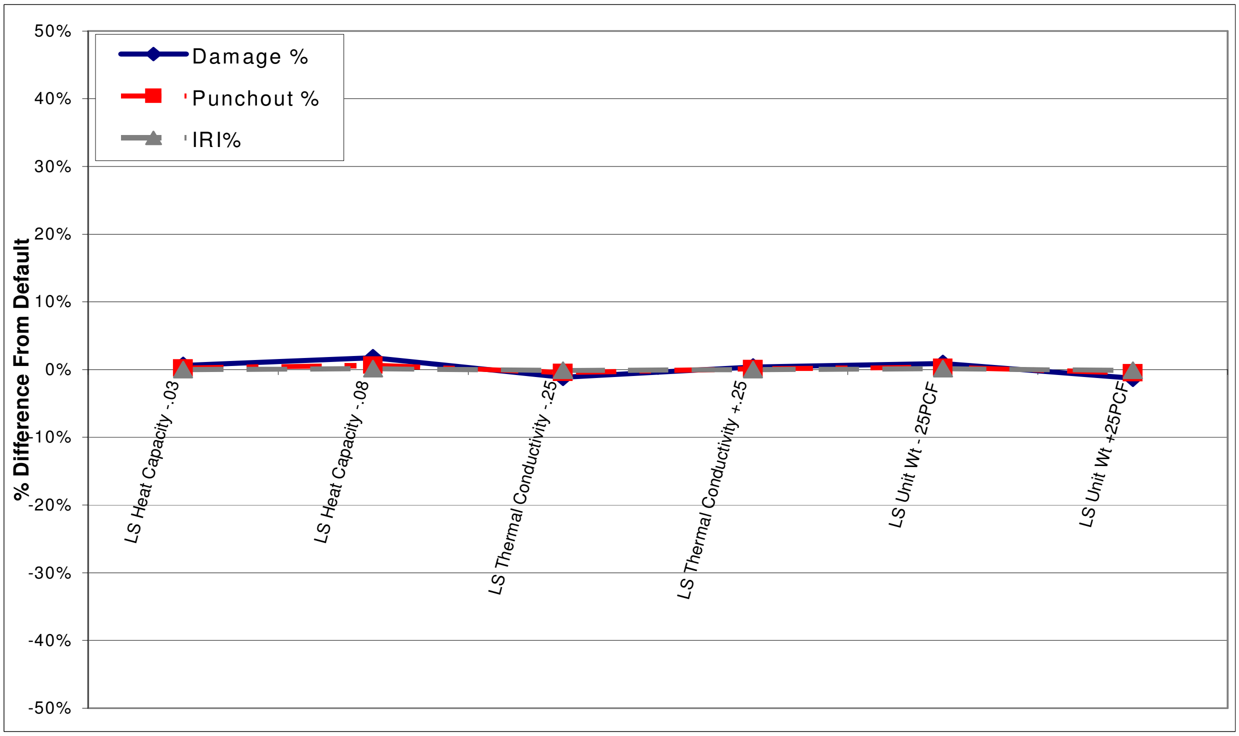

Figure N - 12. Wet-Warm, CRCP Bonded Overlay, Lime Modified ICM Variables.

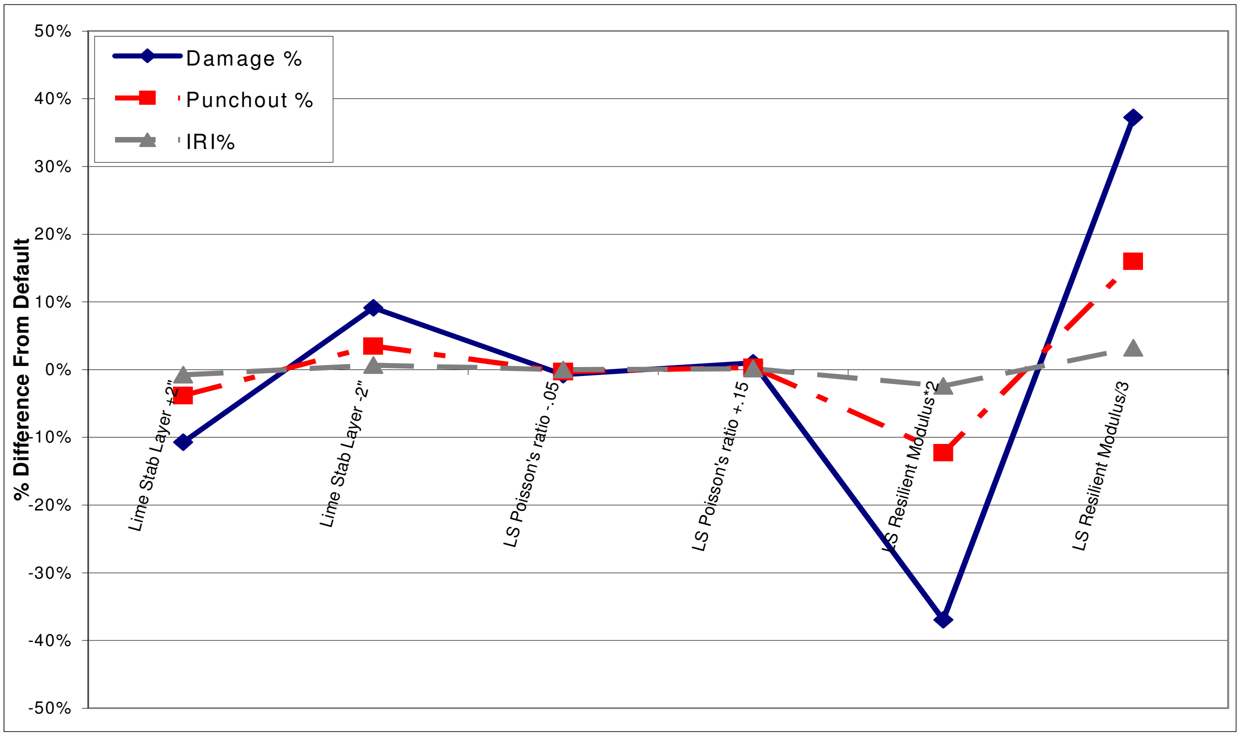

Figure N - 13. Wet-Warm, CRCP Bonded Overlay, Lime Modified Strength Variables.

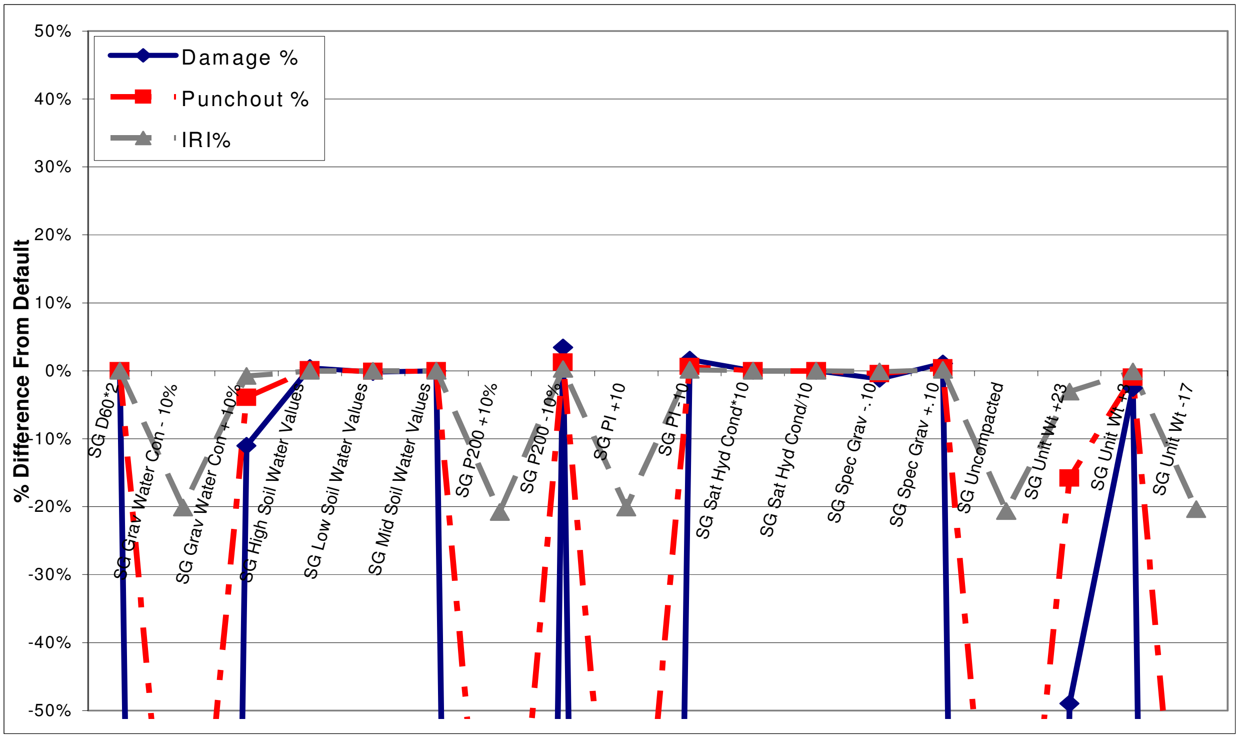

Figure N - 14. Wet-Warm, CRCP Bonded Overlay, Subgrade ICM Variables.

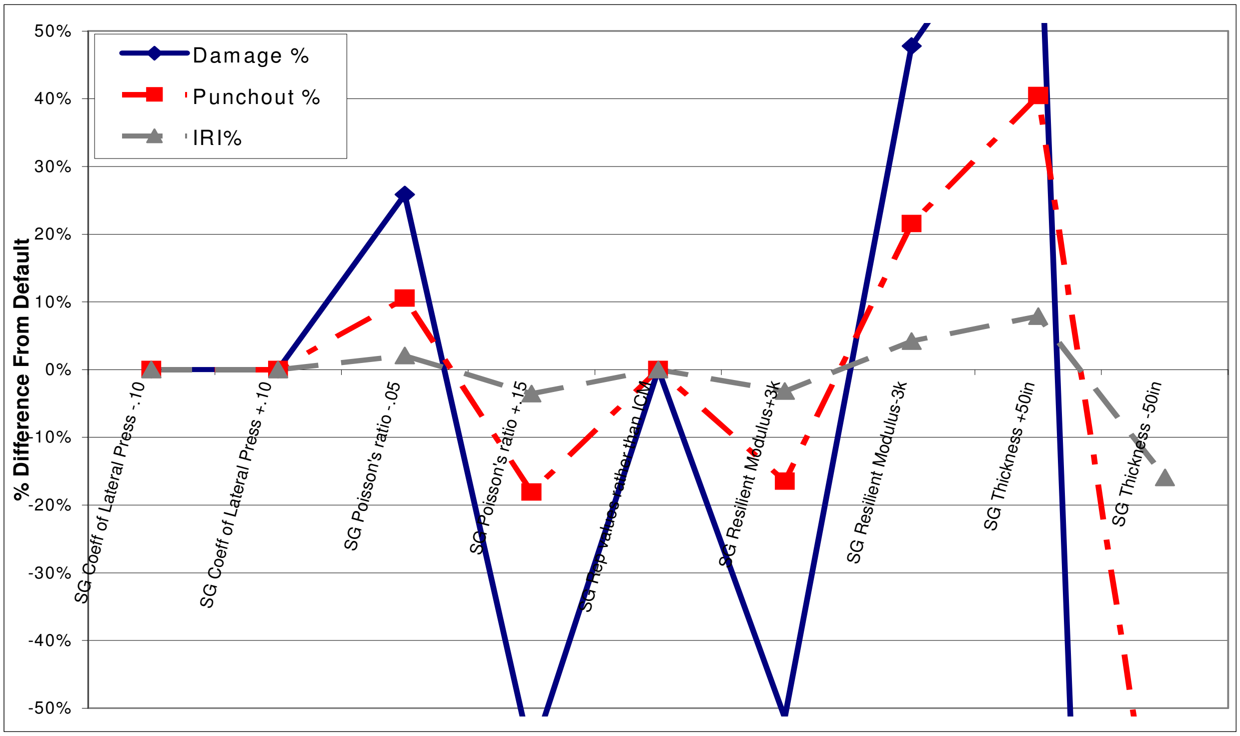

Figure N - 15. Wet-Warm, CRCP Bonded Overlay, Subgrade Strength Variables.

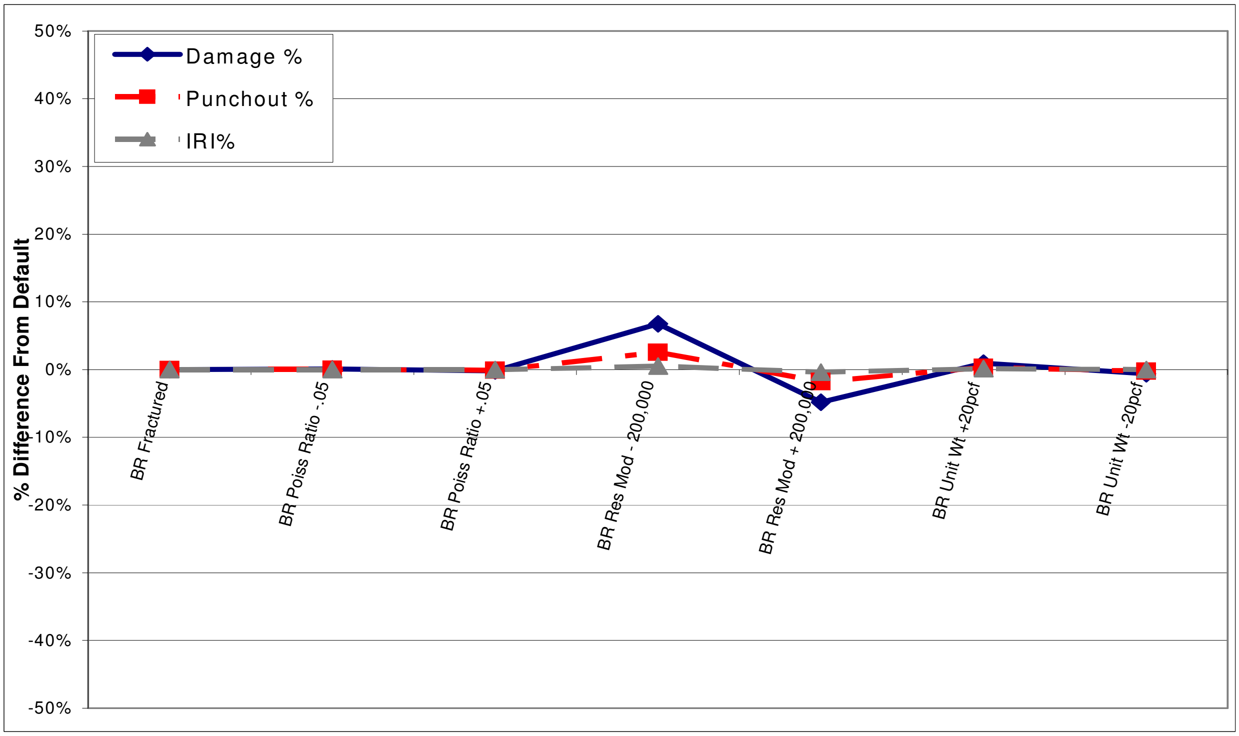

Figure N - 16. Wet-Warm, CRCP Bonded Overlay, Bedrock Variables.

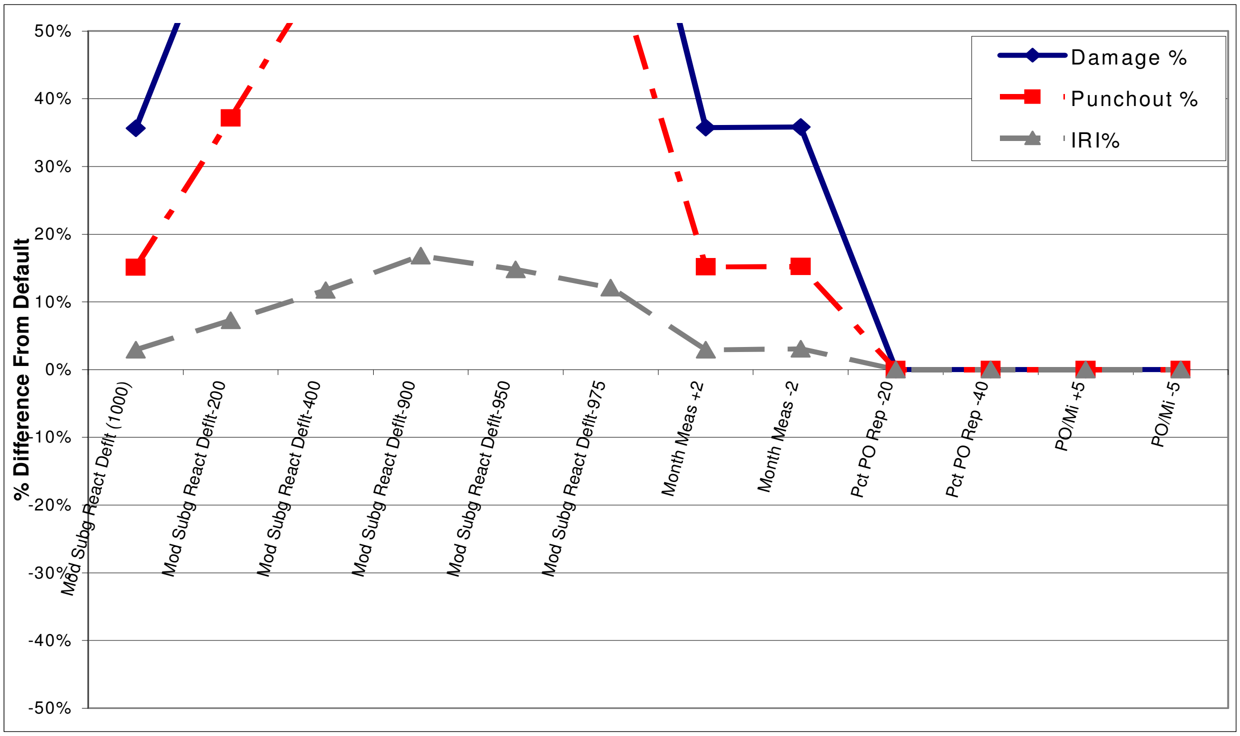

Figure N - 17. Wet-Warm, CRCP Bonded Overlay, Rehabilitation Variables.

Table N-7. Results of Wet-Warm, CRCP Bonded Overlay, General Variables.

Description	Category	Damage %	Punchout %	IRI%
Overlay Construct −5 month	01-General	>	>	>
Overlay Construct +2 month	01-General	>	>	=
Overlay Construct +4 month	01-General	<	=	=
Overlay Traffic +4 month	01-General	>	>	>
Local Road TTC Class 9	02-Site	=	=	=
Minor Arterial TTC Class 4	02-Site	=	=	=

Table N-8. Results of Wet-Warm, CRCP Bonded Overlay, Traffic Variables.

Description	Category	Damage %	Punchout %	IRI%
AADT −1600 (20%)	03-Traffic	> >	> >	> >
AADT +1600 (20%)	03-Traffic	< <	< <	< <
Exist Unit Wt −5 pcf	03-Traffic-General	> >	> >	> >
Lane Width 2' Less	03-Traffic-General	=	=	=
Lane Width 2' More	03-Traffic-General	=	=	=
Wander 2" Less	03-Traffic-General	> >	> >	> >
Wheel Loca 4" Close to lane	03-Traffic-General	< < <	< < <	< < <
Wheel Loca 4" Far to lane	03-Traffic-General	> > >	> > >	> > >
ALL Tire Press +30 psi	03-Traffic-General-Axle	=	=	=
ALL Tire Press −30 psi	03-Traffic-General-Axle	=	=	=
Dual Tire Press +30 psi	03-Traffic-General-Axle	=	=	=
Dual Tire Press −30 psi	03-Traffic-General-Axle	=	=	=
Single Tire Press +30 psi	03-Traffic-General-Axle	=	=	=

Table N-9. Results of Wet-Warm, CRCP Bonded Overlay, Climate Variables.

Description	Category	Damage %	Punchout %	IRI%
Elevation −18'	04-Climate	<	=	=
Elevation +30'	04-Climate	<	=	=
Latitude −0.9	04-Climate	> >	> >	> >
Latitude +0.6	04-Climate	<	<	<
Longitude −0.8	04-Climate	>	>	>
Longitude +0.7	04-Climate	> >	> >	> >
Steel at 2" Depth All PCC	04-Climate	=	=	=
Wander 2" More	04-Climate	< <	< <	< <
Water Table Depth at 1'	04-Climate	> >	> >	> >
Water Table Depth at 100'	04-Climate	< < <	< < <	< < <

Table N-10. Results of Wet-Warm, CRCP Bonded Overlay, DesignVariables.

Description	Category	Damage %	Punchout %	IRI%
AC Shoulder - All PCC	06-Design	=	=	=
Bar Diameter −0.125" All PCC	06-Design	=	=	=
Bar Diameter +0.125" All PCC	06-Design	=	=	=
Base Decrease Erodibility All PCC	06-Design	>	>	>
Base Increase Erodibility All PCC	06-Design	<	<	<
Base/Slab Friction Coeff −3.4 All PCC	06-Design	=	=	=
Base/Slab Friction Coeff +2.9 All PCC	06-Design	=	=	=
Curl/Warp Temp Diff +4 All PCC	06-Design	> > >	> > >	> > >
Curl/Warp Temp Diff −5 All PCC	06-Design	< < <	< < <	< < <
Mean Crack Spacing −18 All PCC	06-Design	=	=	=
Mean Crack Spacing +24 All PCC	06-Design	=	=	=
Mean Crack Spacing - Def All PCC	06-Design	=	=	=
Single Tire Press −30 psi	06-Design	=	=	=
Steel % −0.2% All PCC	06-Design	=	=	=
Steel % +0.2% All PCC	06-Design	=	=	=
Steel at 1/4 Depth All PCC	06-Design	=	=	=

Table N-11. Results of Wet-Warm, CRCP Bonded Overlay, Drainage Variables.

Description	Category	Damage %	Punchout %	IRI%
Cross Slope +2% All PCC	07-Drain	=	=	=
Cross Slope −2% All PCC	07-Drain	=	=	=
Drainage Path +3' All PCC	07-Drain	=	=	=
Drainage Path −2' All PCC	07-Drain	=	=	=
Infiltration-Moderate All PCC	07-Drain	=	=	=
Infiltration-Negligible All PCC	07-Drain	<	<	=

Table N-12. Results of Wet-Warm, CRCP Bonded Overlay, Mix Variables.

Description	Category	Damage %	Punchout %	IRI%
Basalt Aggregate	08-CRC-Mix	=	=	=
Exist Cement Content +47 lb/yd^3	08-CRC-Mix	=	=	=
Exist Cement Content −47 lb/yd^3	08-CRC-Mix	=	=	=
Exist Ultimate Shrink +157 psi	08-CRC-Mix	=	=	=
Exist Ultimate Shrink −143 psi	08-CRC-Mix	=	=	=
Exist Water/Cement Ratio −0.03	08-CRC-Mix	=	=	=
Exist Water/Cement Ratio +0.03	08-CRC-Mix	=	=	=
Exist Zero Stress Temp +19 °F	08-CRC-Mix	=	=	=
Exist Zero Stress Temp −21 °F	08-CRC-Mix	=	=	=
Overlay Cement Content +47 lb/yd^3	08-CRC-Mix	=	=	=
Overlay Cement Content −47 lb/yd^3	08-CRC-Mix	=	=	=
Overlay Chert Aggregate	08-CRC-Mix	=	=	=
Overlay Days to Develop 50% +15	08-CRC-Mix	=	=	=
Overlay Days to Develop 50% −15	08-CRC-Mix	=	=	=
Overlay Granite Aggregate	08-CRC-Mix	=	=	=
Overlay Ultimate Shrink +157 psi	08-CRC-Mix	<	=	=
Overlay Water/Cement Ratio −0.03	08-CRC-Mix	=	=	=
Overlay Water/Cement Ratio +0.03	08-CRC-Mix	=	=	=
Overlay Wet Cure	08-CRC-Mix	>	=	=
Overlay Zero Stress Temp +19 °F	08-CRC-Mix	=	=	=
Overlay Zero Stress Temp 111 °F	08-CRC-Mix	=	=	=
Overlay Zero Stress Temp −21 °F	08-CRC-Mix	=	=	=
Water Table Depth at 20' Def	08-CRC-Mix	=	=	=

Table N-13. Results of Wet-Warm, CRCP Bonded Overlay, Strength Variables.

Description	Category	Damage %	Punchout %	IRI%
Exist E +1000 ksi	08-CRC-Strength	=	=	=
Exist E −800 ksi	08-CRC-Strength	=	=	=
Exist Lev 1 CRC Strength-High	08-CRC-Strength	< < <	< < <	< < <
Exist Lev 1 CRC Strength-Mid	08-CRC-Strength	< <	<	<
Exist Lev 2 High Compress Strength	08-CRC-Strength	< <	< <	< <
Exist Lev 2 Min Compress Strength	08-CRC-Strength	> > >	> > >	> > >
Exist Level 3 Mr −40 psi	08-CRC-Strength	> >	> >	> >
Exist Level 3 Mr +50 psi	08-CRC-Strength	< <	< <	< <
Overlay E +1000 ksi	08-CRC-Strength	=	=	=
Overlay E=4000, Default	08-CRC-Strength	=	=	=
Overlay E −800 ksi	08-CRC-Strength	=	=	=
Overlay Lev 1 CRC Strength-High	08-CRC-Strength	> > >	> > >	> > >
Overlay Lev 1 CRC Strength-Low	08-CRC-Strength	> > >	> > >	> > >
Overlay Lev 1 CRC Strength-Mid	08-CRC-Strength	> > >	> > >	> > >
Overlay Lev 2 Def Compress Strength	08-CRC-Strength	> >	> >	> >
Overlay Lev 2 High Compress Strength	08-CRC-Strength	> > >	> > >	> > >
Overlay Lev 2 Min Compress Strength	08-CRC-Strength	< < <	< < <	< < <
Overlay Level 3 Mr −40 psi	08-CRC-Strength	< < <	< < <	< < <
Overlay Level 3 Mr +50 psi	08-CRC-Strength	> > >	> > >	> > >

Table N-14. Results of Wet-Warm, CRCP Bonded Overlay, Thermal Variables.

Description	Category	Damage %	Punchout %	IRI%
Exist Coeff Contract +3	08-CRC-Thermal	=	=	=
Exist Coeff Contract −2	08-CRC-Thermal	=	=	=
Exist CRC Thick +2"	08-CRC-Thermal	> > >	> > >	> > >
Exist CRC Thick −2"	08-CRC-Thermal	< < <	< < <	< < <
Exist Poisson Ratio −0.05	08-CRC-Thermal	>	>	>
Exist Poisson Ratio +0.05	08-CRC-Thermal	<	<	<
Exist Revers Shrink +25%	08-CRC-Thermal	=	=	=
Exist Revers Shrink −25%	08-CRC-Thermal	=	=	=
Exist Therm Conduct −0.10	08-CRC-Thermal	< <	< <	< <
Exist Therm Conduct +0.20	08-CRC-Thermal	> >	> >	> >
Exist Unit Wt +5 pcf	08-CRC-Thermal	< <	< <	< <
Overlay Coeff Contract +3	08-CRC-Thermal	< < <	< < <	< < <
Overlay Coeff Contract −2	08-CRC-Thermal	> > >	> > >	> > >
Overlay CRC Thick +1"	08-CRC-Thermal	> > >	> > >	> > >
Overlay CRC Thick −1/2"	08-CRC-Thermal	< < <	< < <	< < <
Overlay Poisson Ratio −0.05	08-CRC-Thermal	> >	> >	> >
Overlay Poisson Ratio +0.05	08-CRC-Thermal	< < <	< <	< <
Overlay Revers Shrink +25%	08-CRC-Thermal	<	<	=
Overlay Revers Shrink −25%	08-CRC-Thermal	>	=	=
Overlay Therm Conduct +0.20	08-CRC-Thermal	<	<	<
Overlay Therml Conduct −0.10	08-CRC-Thermal	>	>	>
Overlay Ultimate Shrink −143	08-CRC-Thermal	>	=	=
Overlay Unit Wt +5 pcf	08-CRC-Thermal	> >	> > >	> > >
Overlay Unit Wt −5 pcf	08-CRC-Thermal	< < <	< < <	< < <
Surf Shortwave Absorp −0.05 All PCC	08-CRC-Thermal	> >	> >	> >
Surf Shortwave Absorp +0.05 All PCC	08-CRC-Thermal	< <	< <	< <

Table N-15. Results of Wet-Warm, CRCP Bonded Overlay, AC Binder Variables.

Description	Category	Damage %	Punchout %	IRI%
AC PG Grade 58-22	09-AC-Binder	>	=	=
AC PG Grade 70-34	09-AC-Binder	>	=	=
AC Visc Grade 10	09-AC-Binder	>	=	=
AC Visc Grade 20	09-AC-Binder	=	=	=
AC Visc Grade 5	09-AC-Binder	>	>	=

Table N-16. Results of Wet-Warm, CRCP Bonded Overlay, AC General Variables.

Description	Category	Damage %	Punchout %	IRI%
AC Air Voids +2.5%	09-AC-General	>	=	=
AC Air Voids −2%	09-AC-General	<	=	=
AC Effective Binder Content +3%	09-AC-General	=	=	=
AC Effective Binder Content −3%	09-AC-General	<	=	=
AC Heat Capacity +0.08	09-AC-General	<	<	<
AC Heat Capacity +0.17	09-AC-General	<	<	<
AC Poisson's Ratio −0.05	09-AC-General	=	=	=
AC Poisson's Ratio +0.05	09-AC-General	=	=	=
AC Reference Temp +5 °F	09-AC-General	=	=	=
AC Reference Temp −5 °F	09-AC-General	<	=	=
AC Thermal Conductivity −0.14	09-AC-General	>	>	>
AC Thermal Conductivity +0.14	09-AC-General	<	<	<
AC Unit Wt +6 pcf	09-AC-General	<	=	=
AC Unit Wt −6 pcf	09-AC-General	>	=	=

Table N-17. Results of Wet-Warm, CRCP Bonded Overlay, AC Mix Variables.

Description	Category	Damage %	Punchout %	IRI%
AC % Pass #200 −2%	09-AC-Mix	=	=	=
AC % Pass #200 +2%	09-AC-Mix	<	=	=
AC % Retained #4 +10%	09-AC-Mix	=	=	=
AC % Retained #4 −10%	09-AC-Mix	<	=	=
AC % Retained 3/4" +10%	09-AC-Mix	<	=	=
AC % Retained 3/4" −10%	09-AC-Mix	=	=	=
AC % Retained 3/8" +10%	09-AC-Mix	=	=	=
AC % Retained 3/8" −10%	09-AC-Mix	=	=	=
AC Layer +1"	09-AC-Mix	<<	<<	<<

Table N-18. Results of Wet-Warm, CRCP Bonded Overlay, Lime Stabilized ICM Variables.

Description	Category	Damage %	Punchout %	IRI%
LS Heat Capacity −0.03	10-LS-ICM	>	>	=
LS Heat Capacity −0.08	10-LS-ICM	>	>	>
LS Thermal Conductivity −0.25	10-LS-ICM	<	<	<
LS Thermal Conductivity +0.25	10-LS-ICM	>	>	=
LS Unit Wt −25 pcf	10-LS-ICM	>	>	>
LS Unit Wt +25 pcf	10-LS-ICM	<	<	<

Table N-19. Results of Wet-Warm, CRCP Bonded Overlay, Lime Modified Strength Variables.

Description	Category	Damage %	Punchout %	IRI%
Lime Stab Layer +2"	10-LS-Strength	<<	<<	<<
Lime Stab Layer −2"	10-LS-Strength	>>	>>	>>
LS Poisson’s Ratio −0.05	10-LS-Strength	<	<	=
LS Poisson’s Ratio +0.15	10-LS-Strength	>	>	>
LS Resilient Modulus×2	10-LS-Strength	<<	<<	<<
LS Resilient Modulus/3	10-LS-Strength	>>	>>>	>>>

Table N-20. Results of Wet-Warm, CRCP Bonded Overlay, Subgrade ICM Variables.

Description	Category	Damage %	Punchout %	IRI%
SG D60×2	11-SG-ICM	=	=	=
SG Grav Water Con −10%	11-SG-ICM	< < <	< < <	< < <
SG Grav Water Con +10%	11-SG-ICM	< <	< <	< <
SG High Soil Water Values	11-SG-ICM	>	>	=
SG Low Soil Water Values	11-SG-ICM	<	=	=
SG Mid Soil Water Values	11-SG-ICM	=	=	=
SG P200 +10%	11-SG-ICM	< < <	< < <	< < <
SG P200 −10%	11-SG-ICM	>	>	>
SG PI +10	11-SG-ICM	< < <	< < <	< < <
SG PI −10	11-SG-ICM	>	>	>
SG Sat Hyd Cond×10	11-SG-ICM	=	=	=
SG Sat Hyd Cond/10	11-SG-ICM	=	=	=
SG Spec Grav −0.10	11-SG-ICM	<	<	<
SG Spec Grav +0.10	11-SG-ICM	>	>	>
SG Uncompacted	11-SG-ICM	< < <	< < <	< < <
SG Unit Wt +23 pcf	11-SG-ICM	< < <	< < <	< < <
SG Unit Wt +3 pcf	11-SG-ICM	<	<	<
SG Unit Wt −17 pcf	11-SG-ICM	< < <	< < <	< < <

Table N-21. Results of Wet-Warm, CRCP Bonded Overlay, Subgrade Strength Variables.

Description	Category	Damage %	Punchout %	IRI%
SG Coeff of Lateral Press −0.10	11-SG-Strength	=	=	=
SG Coeff of Lateral Press +0.10	11-SG-Strength	=	=	=
SG Poisson's Ratio −0.05	11-SG-Strength	> >	> >	> >
SG Poisson's Ratio +0.15	11-SG-Strength	< < <	< < <	< < <
SG Rep Values Rather than ICM	11-SG-Strength	=	=	=
SG Resilient Modulus +3 ksi	11-SG-Strength	< < <	< < <	< < <
SG Resilient Modulus −3 ksi	11-SG-Strength	> > >	> > >	> > >
SG Thickness +50"	11-SG-Strength	> > >	> > >	> > >
SG Thickness −50"	11-SG-Strength	< < <	< < <	< < <

Table N-22. Results of Wet-Warm, CRCP Bonded Overlay, Bedrock Variables.

Description	Category	Damage %	Punchout %	IRI%
BR Fractured	12-BR	=	=	=
BR Poiss Ratio −0.05	12-BR	=	=	=
BR Poiss Ratio +0.05	12-BR	<	=	=
BR Res Mod −200,000 ksi	12-BR	>	>	>
BR Res Mod +200,000 ksi	12-BR	<	<	<
BR Unit Wt +20 pcf	12-BR	>	>	>
BR Unit Wt −20 pcf	12-BR	<	<	=

Table N-23. Results of Wet-Warm, CRCP Bonded Overlay, Rehabilitation Variables.

Description	Category	Damage %	Punchout %	IRI%
Mod Subg React Deflt 1000 psi/in.	13-Rehabilitation	> >	> > >	> >
Mod Subg React Deflt −200 psi/in.	13-Rehabilitation	> > >	> > >	> > >
Mod Subg React Deflt −400 psi/in.	13-Rehabilitation	> > >	> > >	> > >
Mod Subg React Deflt −900 psi/in.	13-Rehabilitation	> > >	> > >	> > >
Mod Subg React Deflt −950 psi/in.	13-Rehabilitation	> > >	> > >	> > >
Mod Subg React Deflt −975 psi/in.	13-Rehabilitation	> > >	> > >	> > >
Month Meas +2	13-Rehabilitation	> >	> > >	> >
Month Meas −2	13-Rehabilitation	> >	> > >	> > >
Pct PO Rep −20	13-Rehabilitation	=	=	=
Pct PO Rep −40	13-Rehabilitation	=	=	=
PO/Mi +5	13-Rehabilitation	=	=	=
PO/Mi −5	13-Rehabilitation	=	=	=

APPENDIX O

MULTIPLE VARIABLE ANALYSIS FOR ASPHALT PAVEMENTS

MULTIPLE VARIABLE ANALYSIS FOR ASPHALT PAVEMENTS

O.1 MULTIPLE VARIABLE ANALYSIS - ASPHALT

The computer experimental data for longitudinal cracking, alligator cracking, transverse cracking, subtotal AC rutting, total rutting, and IRI under various factor-level combinations for the Dry-Cold region were analyzed to identify the important factors that affect each distress. Table O-1 contains the factors and their corresponding levels investigated.

Table O-1. Factors for the Dry-Cold Region (Thin).

Factor #	Factor	Level	
1	CS Soil Water Value	Low	High
2	CS Thick	5	7
3	CS Res Mod	100k	25k
4	CHLS Soil Water Value	Low	High
5	CHLS D60	0.5	4
6	CHLS P200	0%	80%
7	CHLS Res Mod	25	45
8	Const Date	Jan	May
9	Road Type	Local	Minor
10	AADT	73	109
11	AC Thick	2"	1"
12	AC PG Grade	58-34	76-22
13	AC Eff Binder	8%	14%
14	AC Air Voids	6.5	11
15	SG Res Mod	7k	17k
16	SG Thick	50	100
17	SG PI	0	20
18	SG Unit Wt	120	100

Analysis of Variance (ANOVA) was employed to analyze the data. Models with the factors in Table O-1 as main effects and all possible two-way interactions were explored for each of the response variables, longitudinal cracking, alligator cracking, transverse cracking, subtotal AC rutting, total rutting, and IRI. There were originally 153 possible two-way interactions in addition to the 18 main effects. The stepwise variable selection procedure (refer to Chapter 8 of Weisberg (1985)) was used to find subsets of the predictors for each response variable.

O.2 LONGITUDINAL CRACKING

For longitudinal cracking, the model in Table O-2 was selected as an adequate model with respect to the terms included. All of the 15 interaction effects retained in the model are statistically significant at the level a=0.05. For the main effects, any terms included in the significant interaction effects are retained in the model as well as the significant main effect SG Res Mod. Note that the main effects CHLS D60, Const Date, AC PG Grade, SG Thick, and SG Unit Wt are not significant by themselves and they are not part of the significant interaction effects either, and so they were excluded from the final model.

Table O-2. Analysis of Variance for Longitudinal Cracking.

Source	**DF**	**Sum of Square**	**Mean Square**	**F Ratio**	**Prob > F**
Model	28	2.50449e10	894459456	148.60	<.0001
CS Soil Water Value	1	1900973502	1900973502	315.82	<.0001
CS Thick	1	27127658	27127658	4.51	0.0356
CS Res Mod	1	9406553512	9406553512	1562.79	<.0001
CHLS Soil Water Value	1	184790110	184790110	30.70	<.0001
CHLS P200	1	108207434	108207434	17.98	<.0001
CHLS Res Mod	1	74468	74468	0.01	0.9116
Road Type	1	30969766	30969766	5.15	0.0249
AADT	1	36900529	36900529	6.13	0.0145
AC Thick	1	5671931095	5671931095	942.32	<.0001
AC Eff Binder	1	952126682	952126682	158.18	<.0001
AC Air Voids	1	1620674203	1620674203	269.26	<.0001
SG Res Mod	1	143352223	143352223	23.82	<.0001
SG PI	1	77092478	77092478	12.81	0.0005
CS Soil WaterValue× CHLS Soil WaterValue	1	105528861	105528861	17.53	<.0001
CS Soil Water Value×CHLS P200	1	179456206	179456206	29.81	<.0001
CS Soil Water Value×AC Thick	1	293308916	293308916	48.73	<.0001
CS Soil Water Value×AC Eff Binder	1	86426694	86426694	14.36	0.0002
CS Thick×AC Thick	1	35250676	35250676	5.86	0.0169
CS Res Mod×AC Thick	1	1354635872	1354635872	225.06	<.0001
CS Res Mod×AC Eff Binder	1	74372767	74372767	12.36	0.0006
CS Res Mod×AC Air Voids	1	335427194	335427194	55.73	<.0001
CHLS Soil Water Value×CHLS P200	1	59300738	59300738	9.85	0.0021
CHLS Soil Water Value×AADT	1	23733802	23733802	3.94	0.0491
CHLS P200×AC Thick	1	27811528	27811528	4.62	0.0334
CHLS Res Mod×AC Eff Binder	1	41708503	41708503	6.93	0.0095
CHLS Res Mod×SG PI	1	48534141	48534141	8.06	0.0052
Road Type×AADT	1	40577555	40577555	6.74	0.0105
AC Thick×AC Eff Binder	1	180193528	180193528	29.94	<.0001
Error	135	812578051	6019097		
C. Total	163	2.58574e10			

Since there are significant interaction effects (joint effects of two factors), the individual factor effects (main effects) can only be assessed conditional on each level of the other factor except for SG Res Mod, which does not interact with any other factors in the model. Figure O-1 contains the least squares means plot for SG Res Mod. It can be concluded from the plot that SG Res Mod level 7k leads to less longitudinal cracking than SG Res Mod level 17k does.

Plots for the statistically significant interaction effects are presented in Figures O-2 through O-16. Interaction plots are often helpful for interpretation of interaction effects. In an interaction plot, the y axis is the average response. An interaction plot shows the effect of two factors on the response. One factor is on the x axis. This factor's effect shows as the slope of the line segments in the plot. The other factor becomes multiple prediction line segments as it varies from one level to another. This factor shows its effect on the response as the vertical separation of the line segments. If the slopes are different for different line segments, it is probably an indication of an interaction effect, i.e., the change in true average response when the level of one factor changes depends on the level of the other factor. If the connected line segments are close to parallel, it is probably an indication of no interaction effect among the factors used in the plot. The conclusions drawn based on the interaction plots, Figures O-2 through O-16, and the multiple comparison procedures are presented right after each interaction plot. Multiple comparison procedures are used to determine if the differences in the average responses at different factor levels are statistically significant. For space, the tables containing the results of multiple comparison procedures are not presented here.

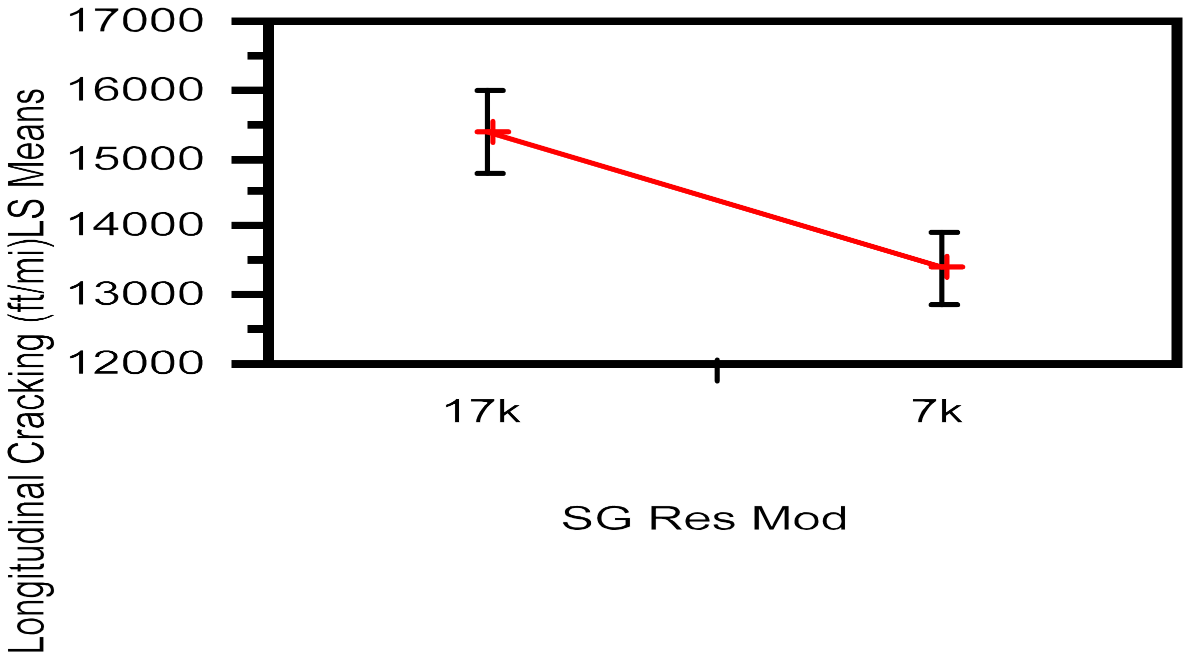

Figure O-1. Least Squares Means Plot for SG Res Mod (Longitudinal Cracking).

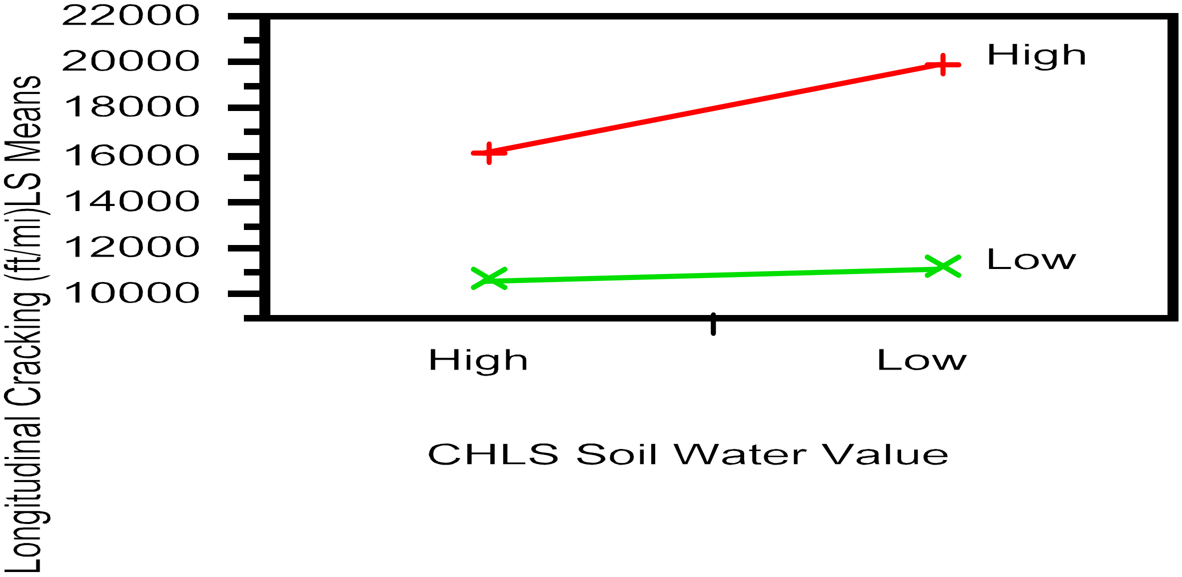

Figure O-2. Interaction Plot for CS Soil Water Value×CHLS Soil Water Value (Longitudinal Cracking).

CHLS Soil Water Value matters when CS Soil Water Value is High, i.e., low CHLS Soil Water Value leads to more longitudinal cracking, but no effect of CHLS Soil Water Value is observed when CS Soil Water Value is Low.

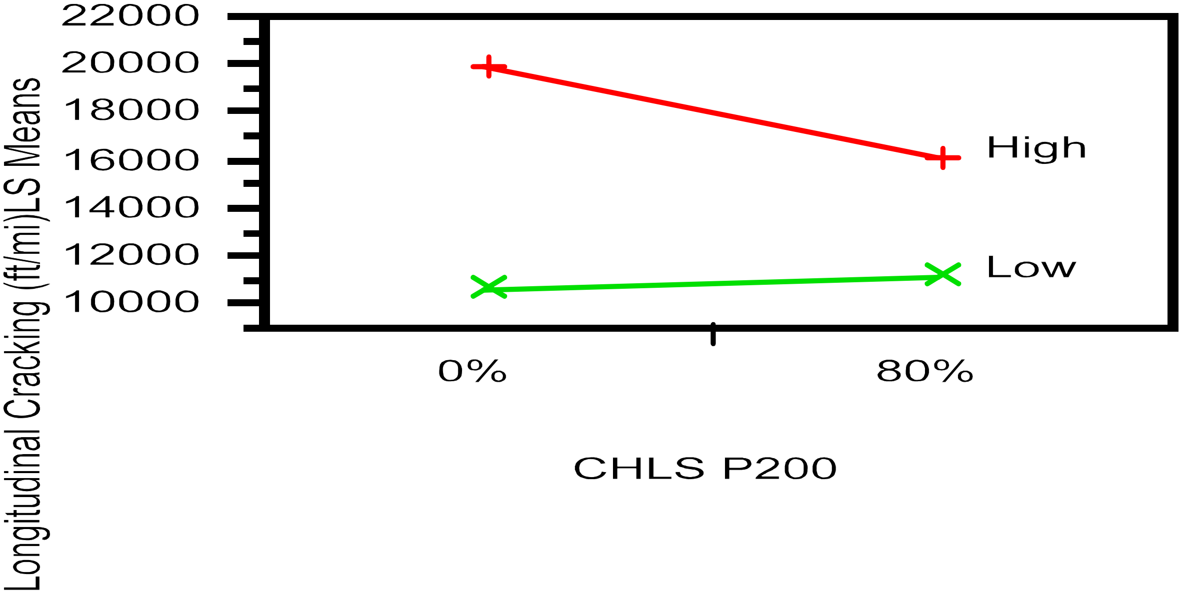

Figure O-3. Interaction Plot for CS Soil Water Value×CHLS P200 (Longitudinal Cracking).

CHLS P200 matters when CS Soil Water Value is High, i.e., CHLS P200 level 80% leads to less longitudinal cracking than CHLS P200 level 0% does, but no effect of CHLS P200 is observed when CS Soil Water Value is Low.

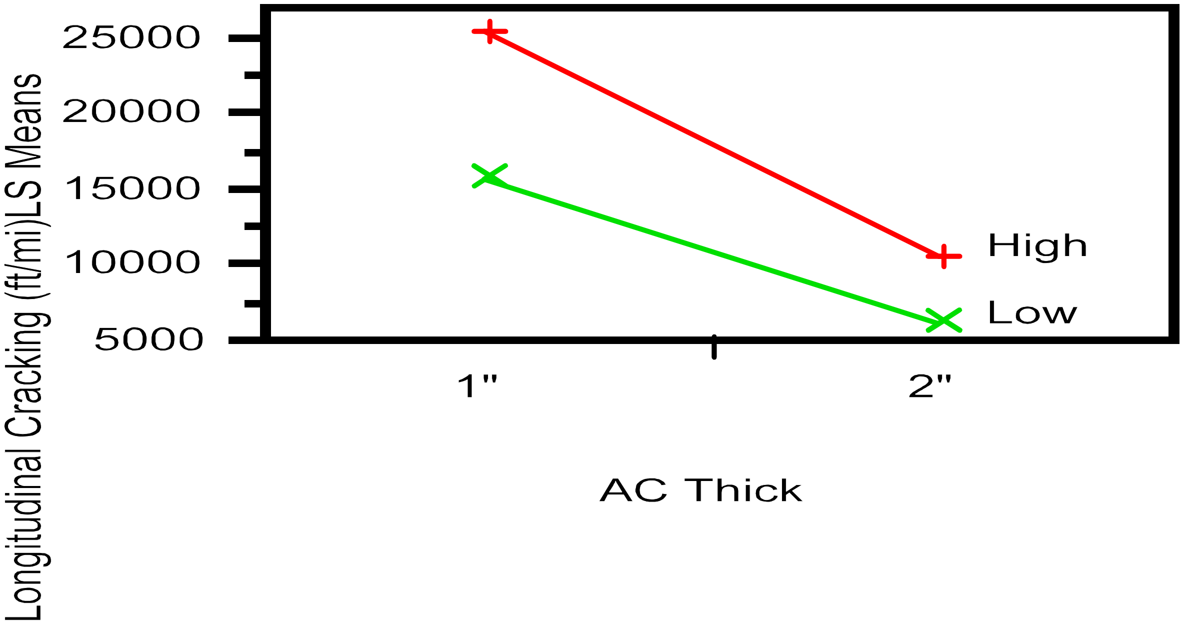

Figure O-4. Interaction Plot for CS Soil Water Value×AC Thick (Longitudinal Cracking).

The effect of AC Thick is slightly different for each level of CS Soil Water Value. In general, AC Thick level 2" leads to less longitudinal cracking than does AC Thick level 1", regardless of the levels of CS Soil Water Value. However, the magnitude of decrease in longitudinal cracking when AC Thick level changes from 1" to 2" is slightly different for each level of CS Soil Water Value. The effect of AC Thick is larger when CS Soil Water Value is High.

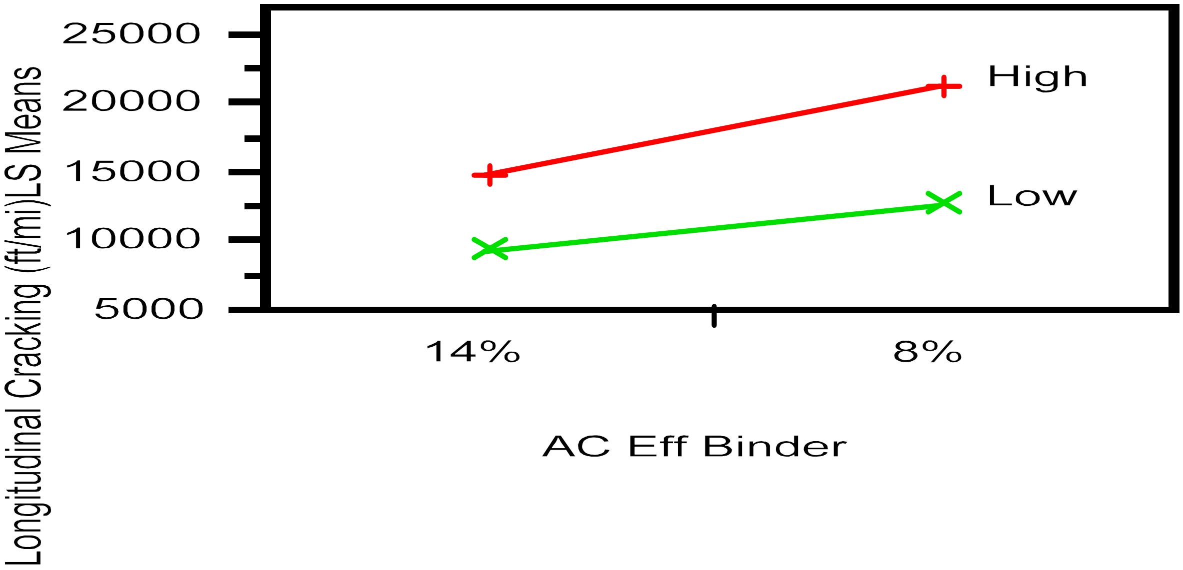

Figure O-5. Interaction Plot for CS Soil Water Value×AC Eff Binder (Longitudinal Cracking).

The effect of AC Eff Binder is slightly different for each level of CS Soil Water Value. In general, AC Eff Binder level 8% leads to more longitudinal cracking than AC Eff Binder level 14% does, regardless of the levels of CS Soil Water Value. However, the magnitude of increase in longitudinal cracking when AC Eff Binder level changes from 14% to 8% is slightly different for each level of CS Soil Water Value. The effect of AC Eff Binder is larger when CS Soil Water Value is High.

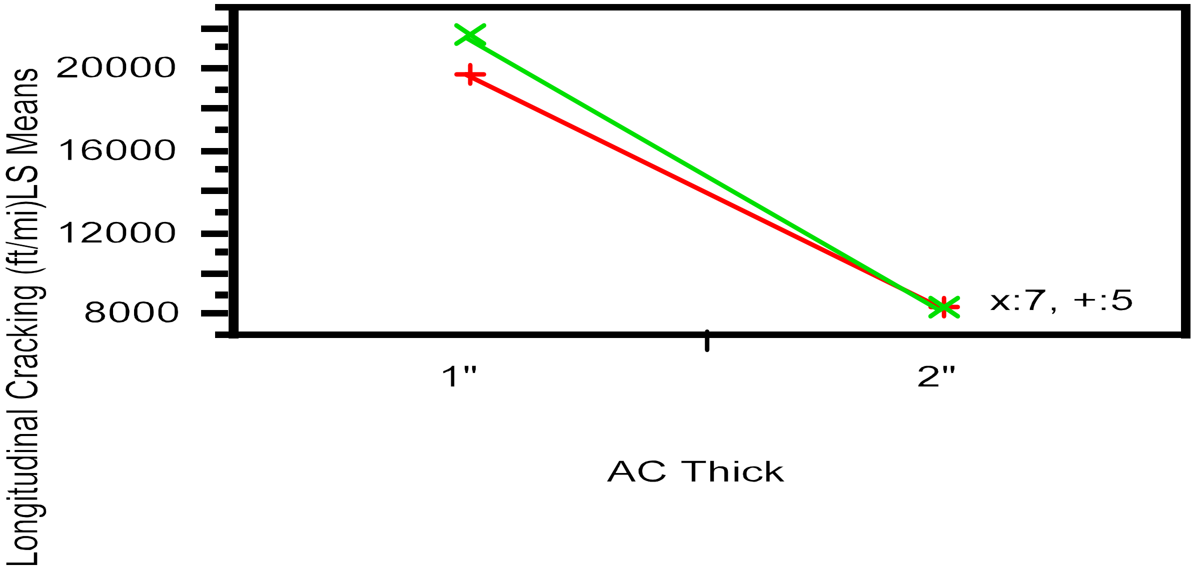

Figure O-6. Interaction Plot for CS Thick×AC Thick (Longitudinal Cracking).

CS Thick level matters when AC Thick is 1", i.e., CS Thick level 5 leads to less longitudinal cracking than CS Thick level 7 does, but no effect of CS Thick is observed when AC Thick is 2".

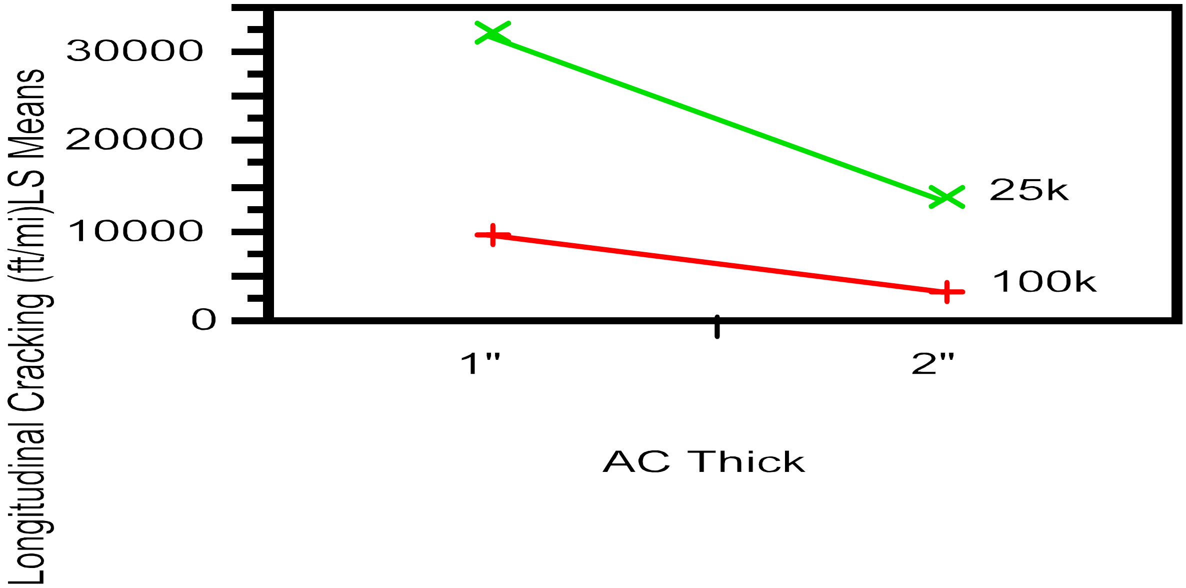

Figure O-7. Interaction Plot for CS Res Mod×AC Thick (Longitudinal Cracking).

The effect of AC Thick is different for each level of CS Res Mod. In general, AC Thick level 2" leads to less longitudinal cracking than AC Thick level 1" does, regardless of the levels of CS Res Mod. However, the magnitude of decrease in longitudinal cracking when AC Thick level changes from 1" to 2" is different for each level of CS Res Mod. The effect of AC Thick is larger when CS Res Mod is 25k.

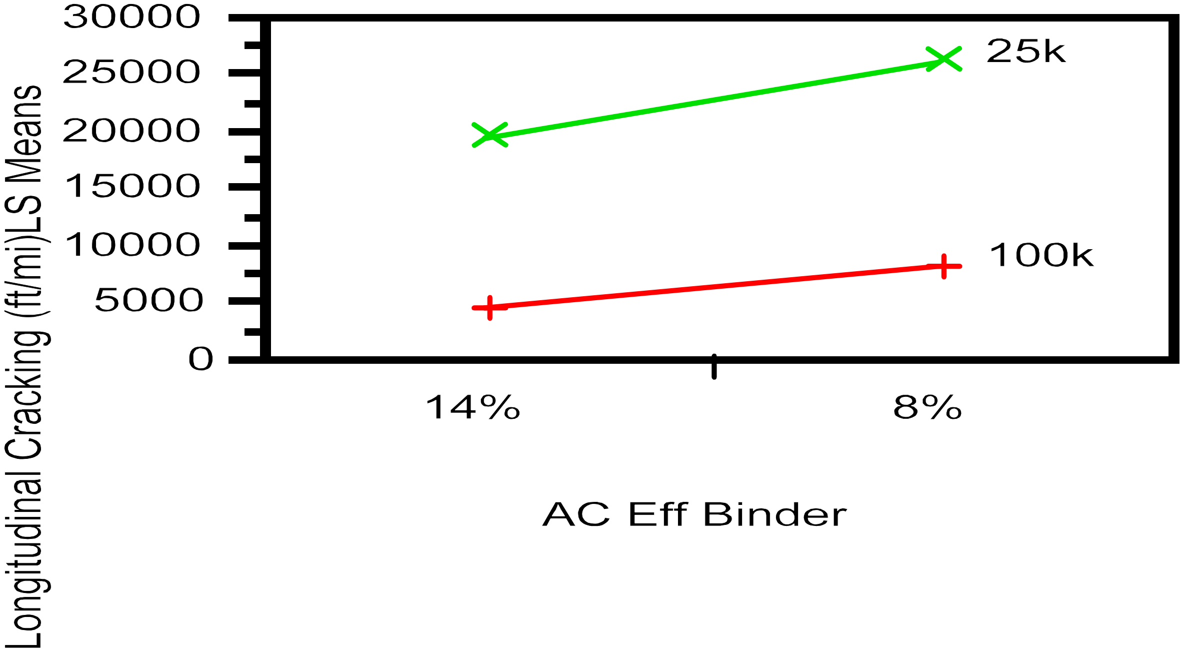

Figure O-8. Interaction Plot for CS Res Mod×AC Eff Binder (Longitudinal Cracking).

The effect of AC Eff Binder is slightly different for each level of CS Res Mod. In general, AC Eff Binder level 8% leads to more longitudinal cracking than AC Eff Binder level 14% does, regardless of the levels of CS Res Mod. However, the magnitude of increase in longitudinal cracking when AC Eff Binder level changes from 14% to 8% is slightly different for each level of CS Res Mod. The effect of AC Eff Binder is slightly larger when CS Res Mod is 25k.

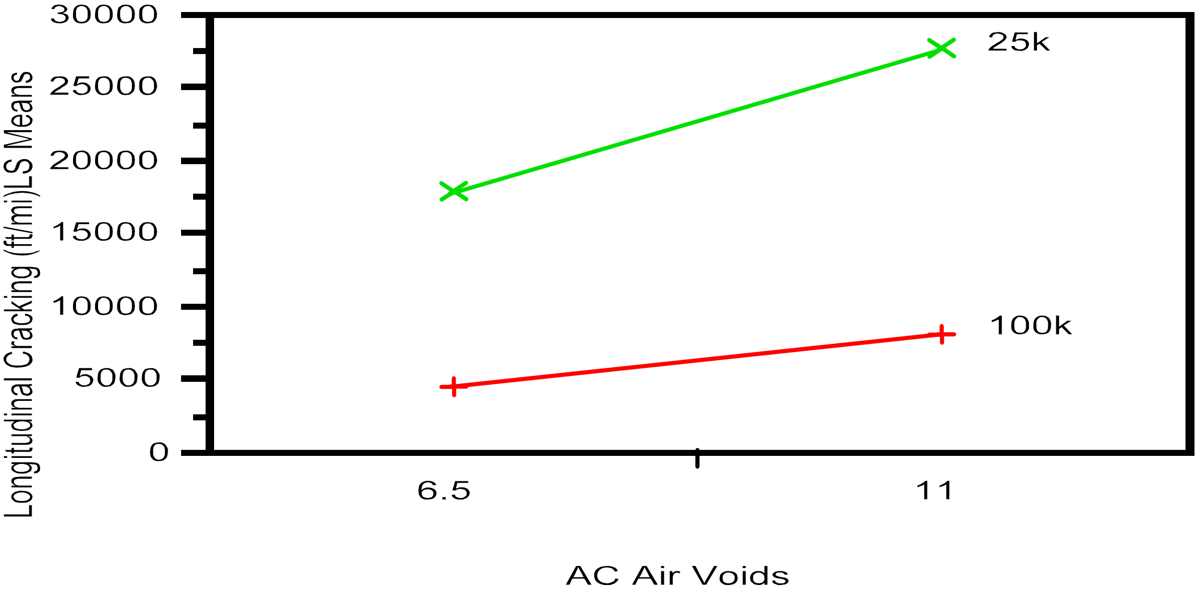

Figure O-9. Interaction Plot for CS Res Mod*AC Air Voids (Longitudinal Cracking).

The effect of AC Air Voids is slightly different for each level of CS Res Mod. In general, AC Air Voids level 11 leads to more longitudinal cracking than AC Air Voids level 6.5 does, regardless of the levels of CS Res Mod. However, the magnitude of increase in longitudinal cracking when AC Air Voids level changes from 6.5 to 11 is different for each level of CS Res Mod. The effect of AC Air Voids is larger when CS Res Mod is 25k.

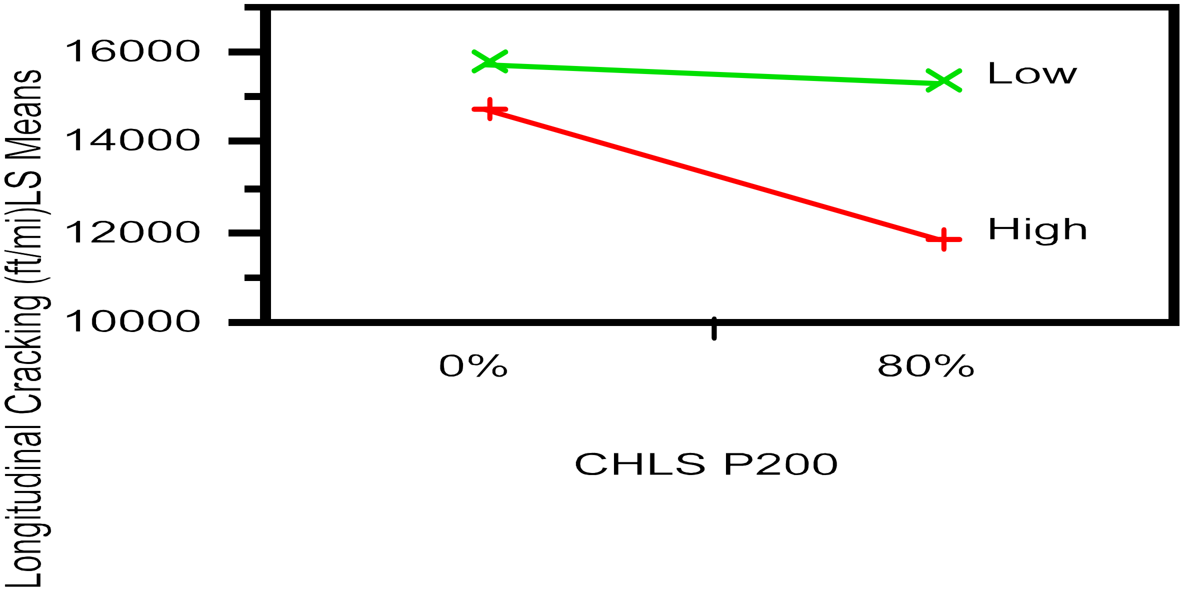

Figure O-10. Interaction Plot for CHLS Soil Water Value×CHLS P200 (Longitudinal Cracking).

CHLS P200 matters when CHLS Soil Water Value is High, but not when CHLS Soil Water Value is Low. Also, CHLS Soil Water Value matters when CHLS P200 is 80%, but not when CHLS P200 is 0%. The predicted longitudinal cracking is lower when CHLS P200 is 80% and CHLS Soil Water Value is High, but for the other factor-level combinations of CHLS P200 and CHLS Soil Water Value, there is no statistically significant difference in the predicted longitudinal cracking.

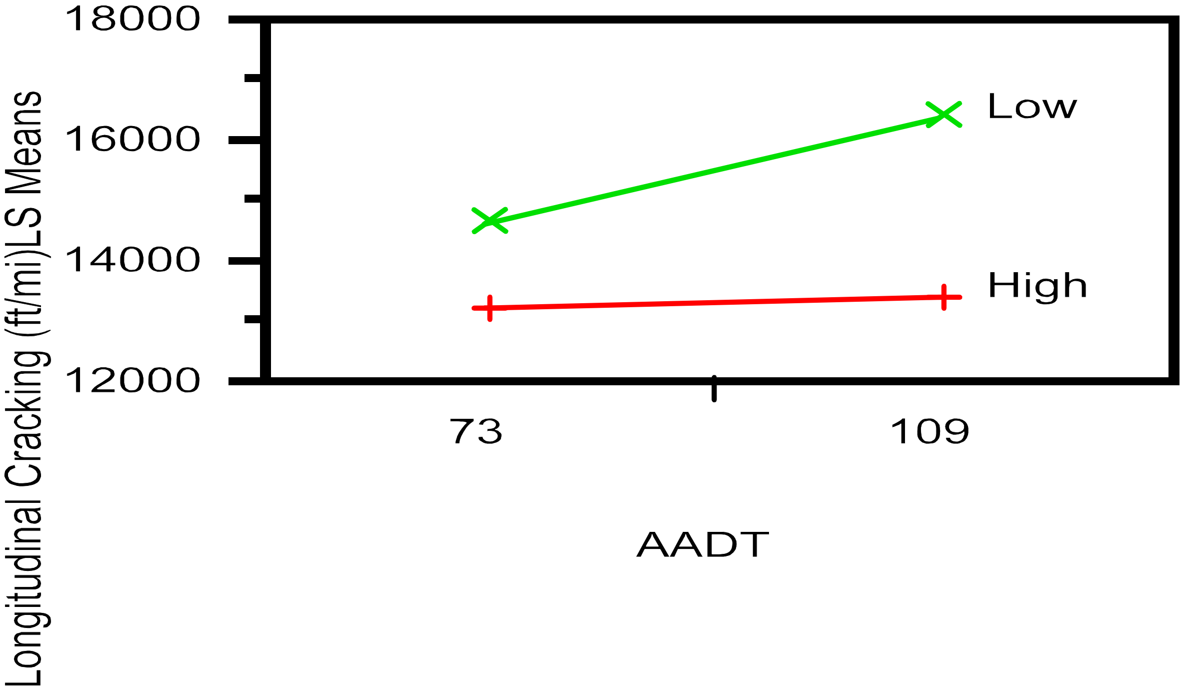

Figure O-11. Interaction Plot for CHLS Soil Water Value×AADT (Longitudinal Cracking).

AADT matters for Low CHLS Soil Water Value, but not for High CHLS Soil Water Value. Said another way, CHLS Soil Water Value matters when AADT is 109, but not when AADT is 73. More longitudinal cracking is expected when AADT is 109 and CHLS Soil Water Value is Low, but for the other factor-level combinations of AADT and CHLS Soil Water Value, there is no statistically significant difference in the expected value of longitudinal cracking.

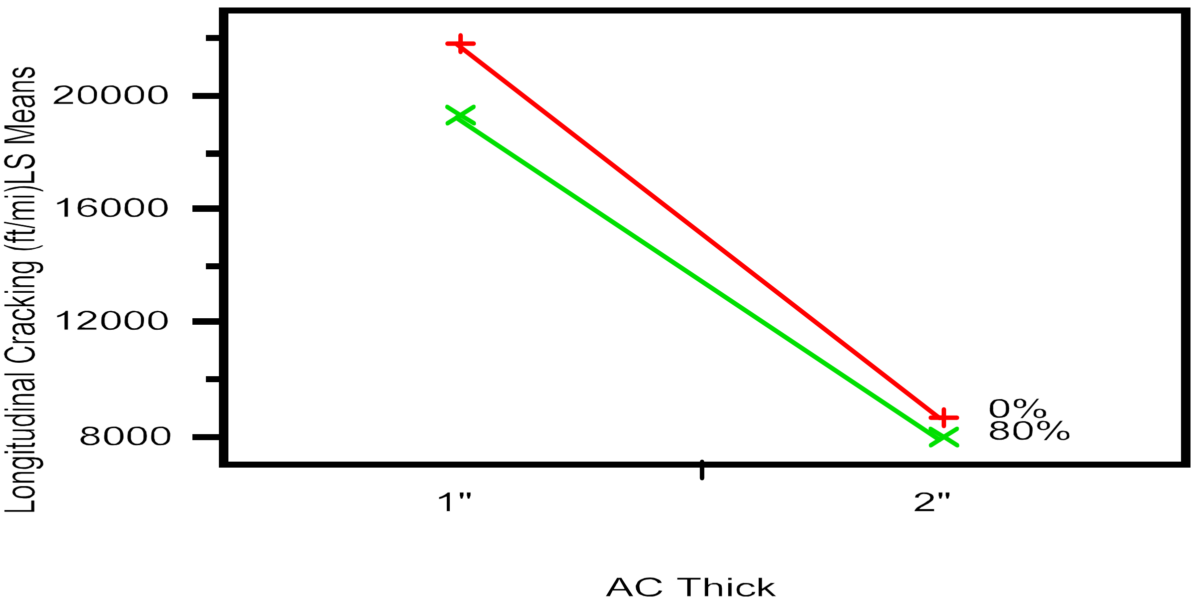

Figure O-12. Interaction Plot for CHLS P200*AC Thick (Longitudinal Cracking).

The level of CHLS P200 matters for 1" AC Thick, but not for 2" AC Thick. The level of AC Thick 2" leads to less longitudinal cracking than 1" does whether CHLS P200 is 0% or 80%.

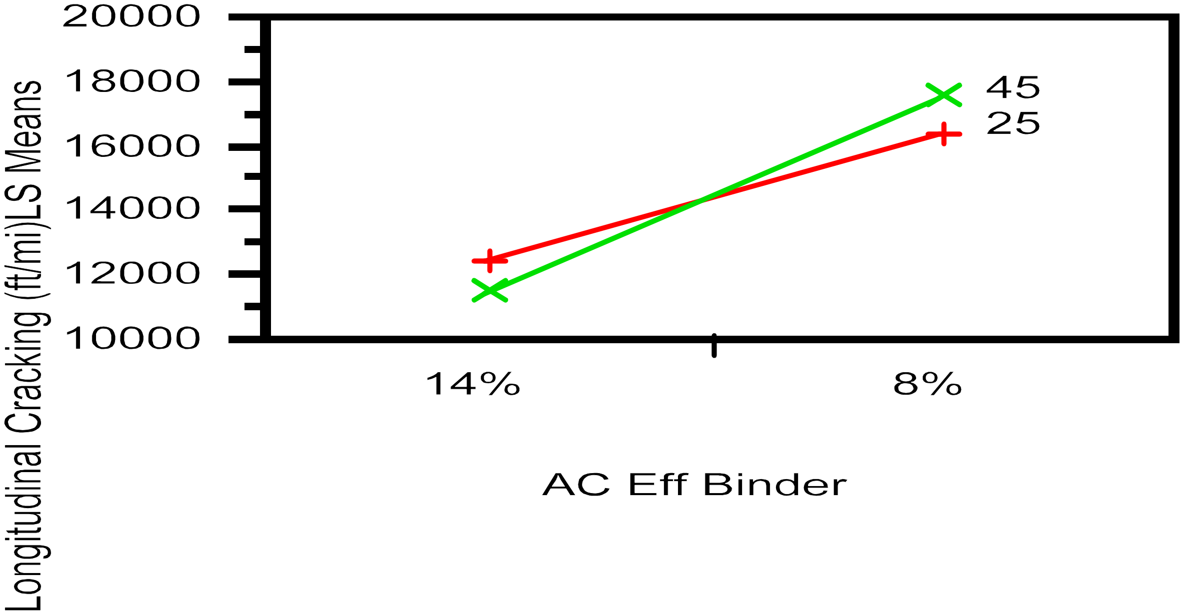

Figure O-13. Interaction Plot for CHLS Res Mod×AC Eff Binder (Longitudinal Cracking).

The effect of AC Eff Binder is slightly different for each level of CHLS Res Mod. The magnitude of increase in longitudinal cracking when the level of AC Eff Binder changes from 14% to 8% is larger for CHLS Res Mod 45 than for CHLS Res Mod 25. The effect of CHLS Res Mod is insignificant at both levels of AC Eff Binder.

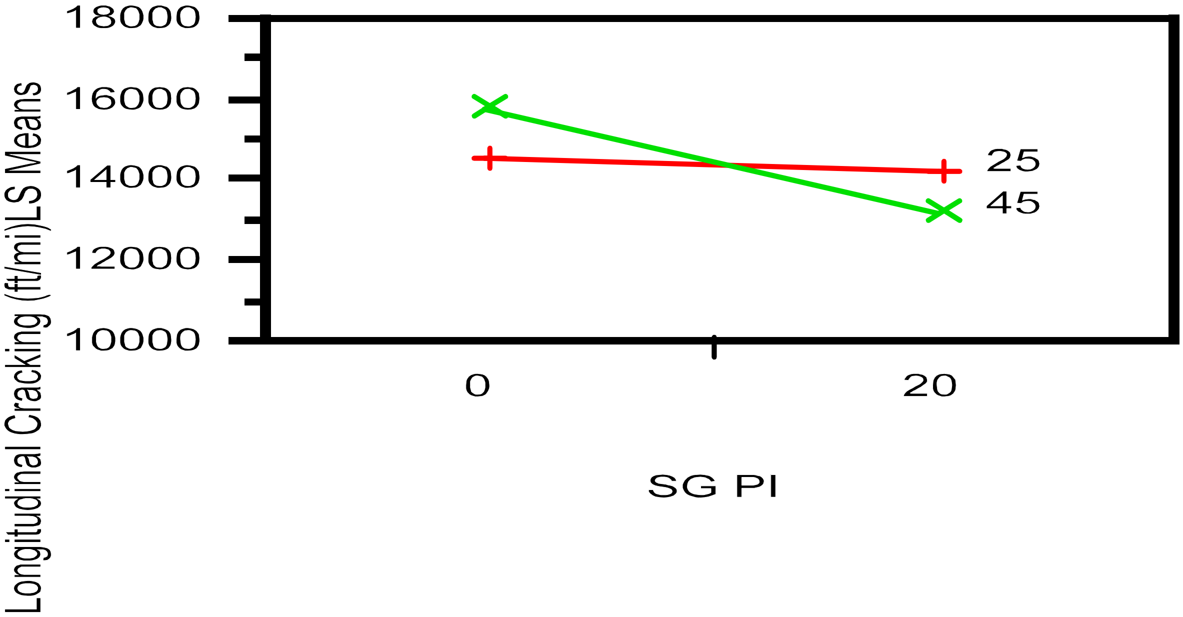

Figure O-14. Interaction Plot for CHLS Res Mod×SG PI (Longitudinal Cracking).

SG PI matters when CHLS Res Mod is 45, but not when CHLS Res Mod is 25. The effect of CHLS Res Mod is insignificant at both levels of SG PI.

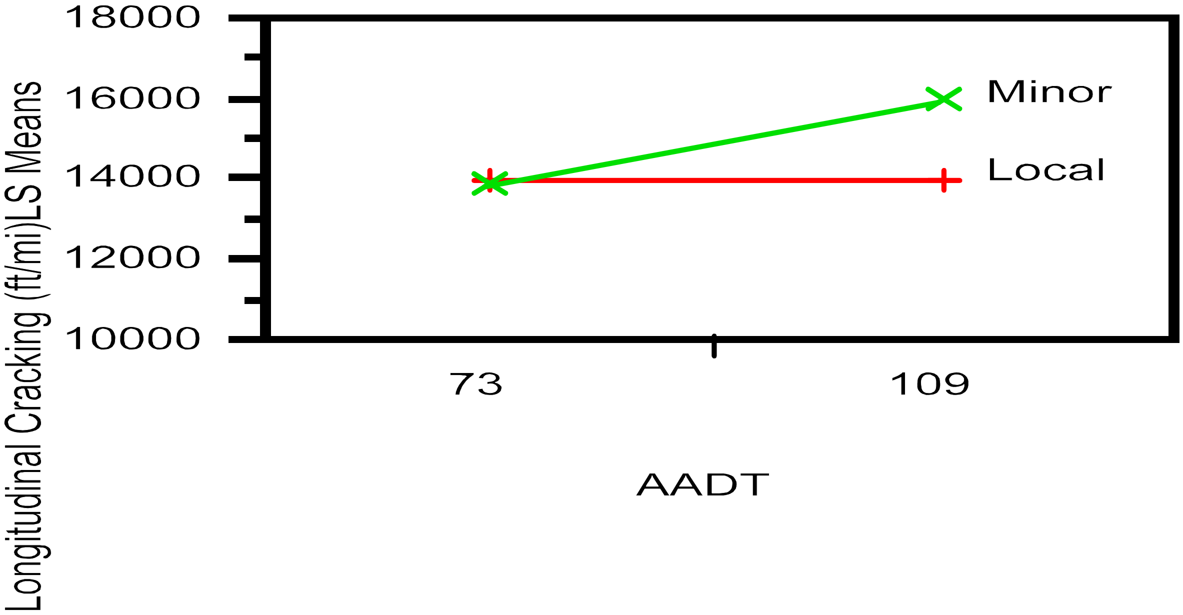

Figure O-15. Interaction Plot for Road Type×AADT (Longitudinal Cracking).

The AADT matters for minor roads, but not for local roads. Said another way, the road type matters for AADT = 109 but not for AADT = 73.

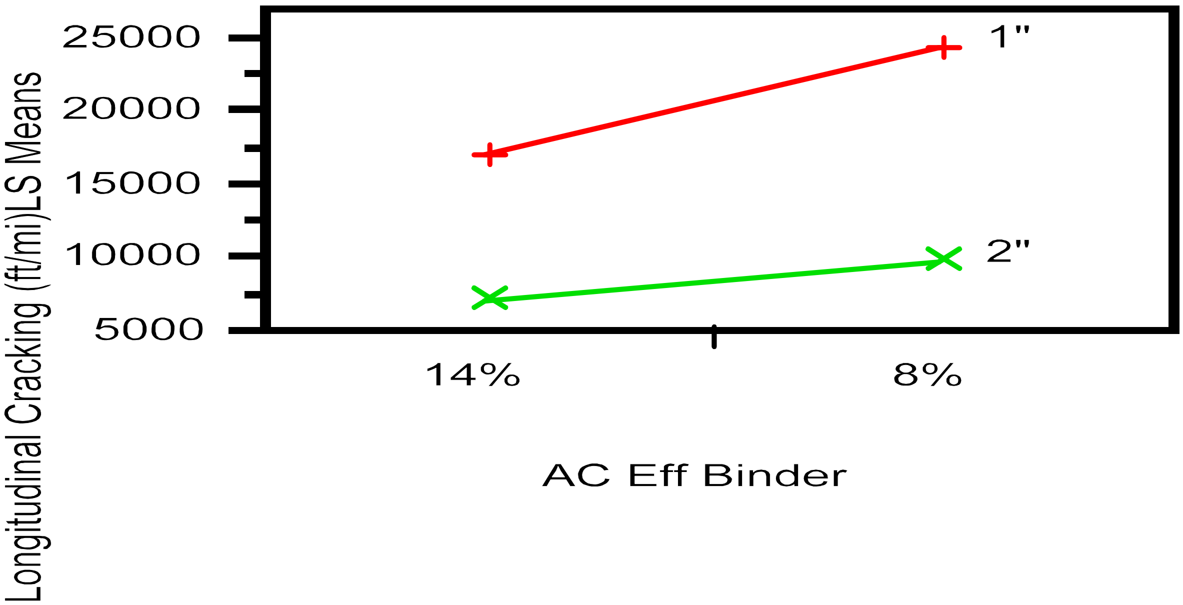

Figure O-16. Interaction Plot for AC Thick×AC Eff Binder (Longitudinal Cracking).

The effect of AC Eff Binder is slightly different for each level of AC Thick. The magnitude of increase in longitudinal cracking when the level of AC Eff Binder changes from 14% to 8% is larger for 1" AC Thick than for 2" AC Thick. The magnitude of increase in longitudinal cracking when the level of AC Thick changes from 2" to 1" is larger for 8% AC Eff Binder than 14% AC Eff Binder.

O.3 ALLIGATOR CRACKING

For alligator cracking, the model in Table O-3 was selected to be adequate in modeling the parameters with respect to the terms included by a forward variable selection procedure. All 20 interaction effects retained in the model are statistically significant at the level a = 0.05. For the main effects, terms included in the significant interaction effects are retained in the model. Note that the main effects CHLS D60 and Road Type are not significant by themselves and are not part of the significant interaction effects either, so they were excluded from the final model.

Since there are significant interaction effects (joint effects of two factors), the individual factor effects (main effects) can only be assessed conditional on each level of the other factor. Plots for the statistically significant interaction effects are presented in Figures O-17 through O-35. The conclusions drawn based on those plots and the multiple comparison procedures are presented right after each plot. Multiple comparison procedures are used to determine if the differences in the average responses at different factor levels are statistically significant. For space, the tables containing the results of multiple comparison procedures are not presented here.

Table O-3 Analysis of Variance for Alligator Cracking.

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Model	36	260742.5	7242.9	68.65	<.0001
CS Soil Water Value	1	30994.5	30994.5	293.78	<.0001
CS Thick	1	2.5	2.6	0.02	0.8766
CS Res Mod	1	118643.4	118643.4	1124.56	<.0001
CHLS Soil Water Value	1	39.1	39.1	0.37	0.5439
CHLS P200	1	593.4	593.4	5.62	0.0192
CHLS Res Mod	1	65.9	65.9	0.62	0.4307
Const Date	1	34.1	34.1	0.32	0.5708
AADT	1	358.4	358.4	3.40	0.0676
AC Thick	1	81.1	81.1	0.77	0.3823
AC PG Grade	1	78.7	78.7	0.75	0.3894
AC Eff Binder	1	5098.7	5098.7	48.33	<.0001
AC Air Voids	1	4800.3	4800.3	45.50	<.0001
SG Res Mod	1	0.2	0.2	0.002	0.9693
SG Thick	1	214.6	214.6	2.03	0.1563
SG PI	1	159.0	159.0	1.51	0.2219
SG Unit Wt	1	20.8	20.8	0.20	0.6577
CS Soil Water Value×CS Res Mod	1	25561.7	25561.7	242.29	<.0001
CS Soil Water Value×CHLS P200	1	1643.3	1643.3	15.58	0.0001
CS Soil Water Value×AC Thick	1	1156.4	1156.4	10.96	0.0012
CS Soil Water Value×AC Eff Binder	1	990.8	990.8	9.39	0.0027
CS Thick×Const Date	1	1471.0	1471.0	13.94	0.0003
CS Res Mod×CHLS P200	1	1532.7	1532.7	14.53	0.0002
CS Res Mod×AC Thick	1	1498.3	1498.3	14.20	0.0003
CS Res Mod×AC Eff Binder	1	3625.6	3625.5	34.36	<.0001
CS Res Mod×AC Air Voids	1	928.5	928.5	8.80	0.0036
CHLS Soil Water Value×CHLS P200	1	2415.4	2415.4	22.89	<.0001
CHLS P200×SG Thick	1	868.3	868.3	8.30	0.0048
CHLS Res Mod×AADT	1	654.6	654.6	6.20	0.0140
CHLS Res Mod×AC PG Grade	1	998.3	998.3	9.46	0.0026
Const Date×AC Air Voids	1	828.6	828.6	7.85	0.0059
AC Thick×AC Eff Binder	1	868.0	868.0	8.23	0.0048
AC Thick×SG Thick	1	1488.57	1488.57	14.11	0.0003
AC PG Grade×SG Res Mod	1	918.84	918.84	8.71	0.0038
AC Eff Binder×AC Air Voids	1	2764.89	2764.89	26.21	<.0001
SG Res Mod×SG Unit Wt	1	1388.31	1388.31	13.16	0.0004
SG PI×SG Unit Wt	1	750.53	750.53	7.11	0.0086
Error	127	13398.76	105.50		
C. Total	163	274141.28			

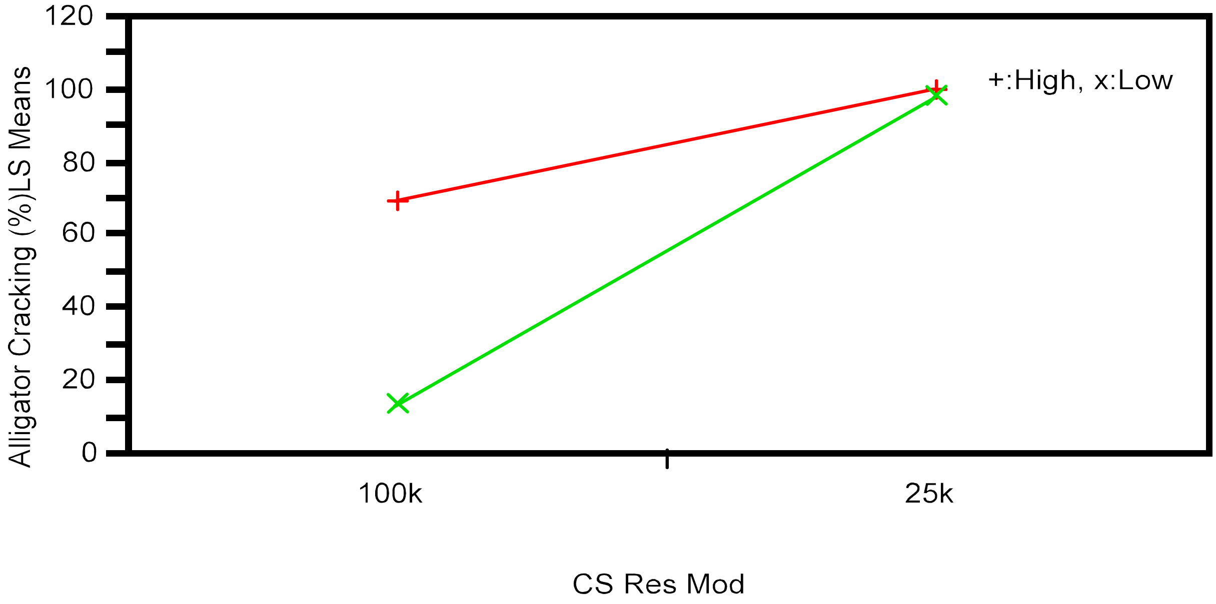

Figure O-17. Interaction Plot for CS Soil Water Value×CS Res Mod (Alligator Cracking).

In general, CS Res Mod 25k leads to more alligator cracking than CS Res Mod 100k does. CHLS Soil Water Value matters when CS Res Mod is 100k, i.e., high CHLS Soil Water Value leads to more alligator cracking when CS Res Mod is 100k, but no statistically significant effect of CHLS Soil Water Value is observed when CS Res Mod is 25k.

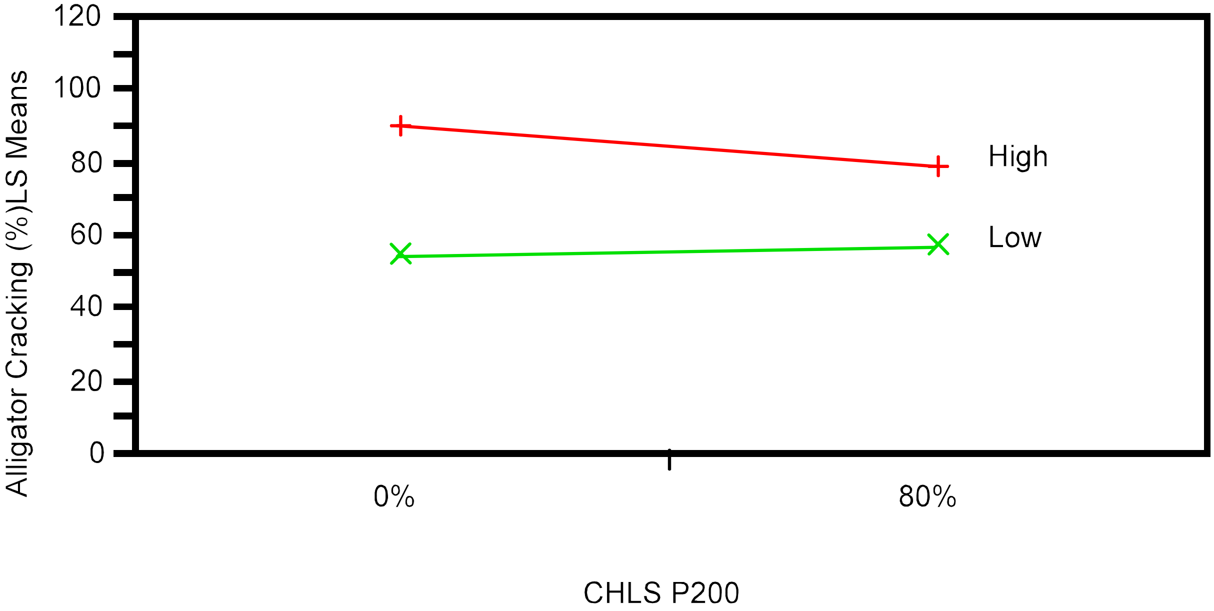

Figure O-18. Interaction Plot for CS Soil Water Value×CHLS P200 (Alligator Cracking).

CHLS P200 matters when CS Soil Water Value is High, i.e., CHLS P200 level 80% leads to less alligator cracking than CHLS P200 level 0% does, but no statistically significant effect of CHLS P200 is observed when CS Soil Water Value is Low.

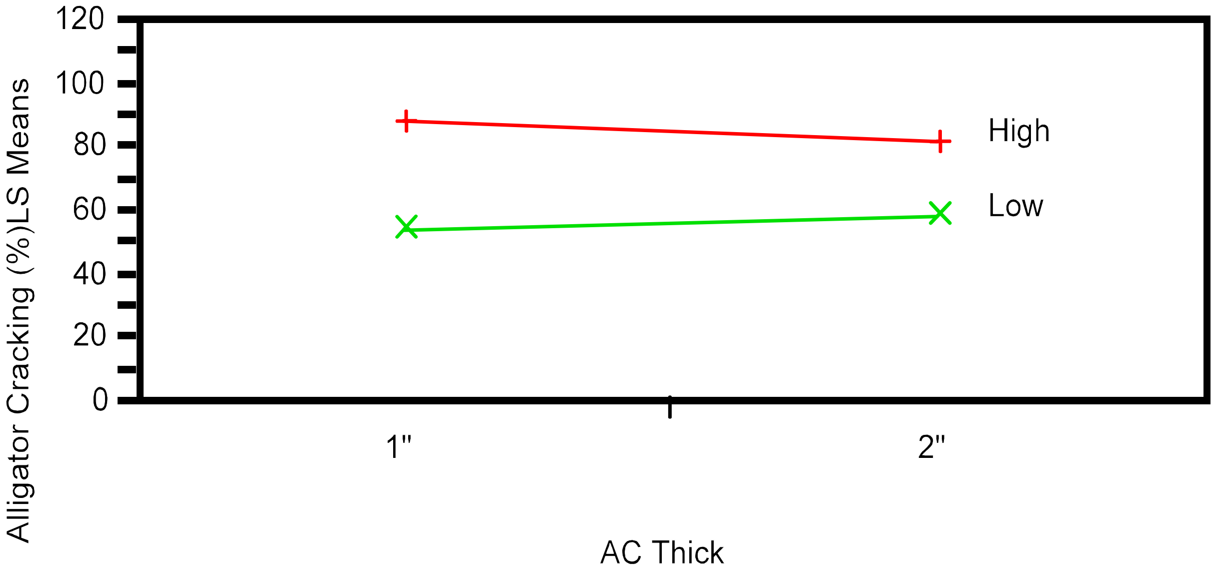

Figure O-19. Interaction Plot for CS Soil Water Value×AC Thick (Alligator Cracking).

AC Thick matters when CS Soil Water Value is High, i.e., AC Thick level 2" leads to slightly less alligator cracking than AC Thick level 1" does, but no effect of AC Thick is observed when CS Soil Water Value is Low.

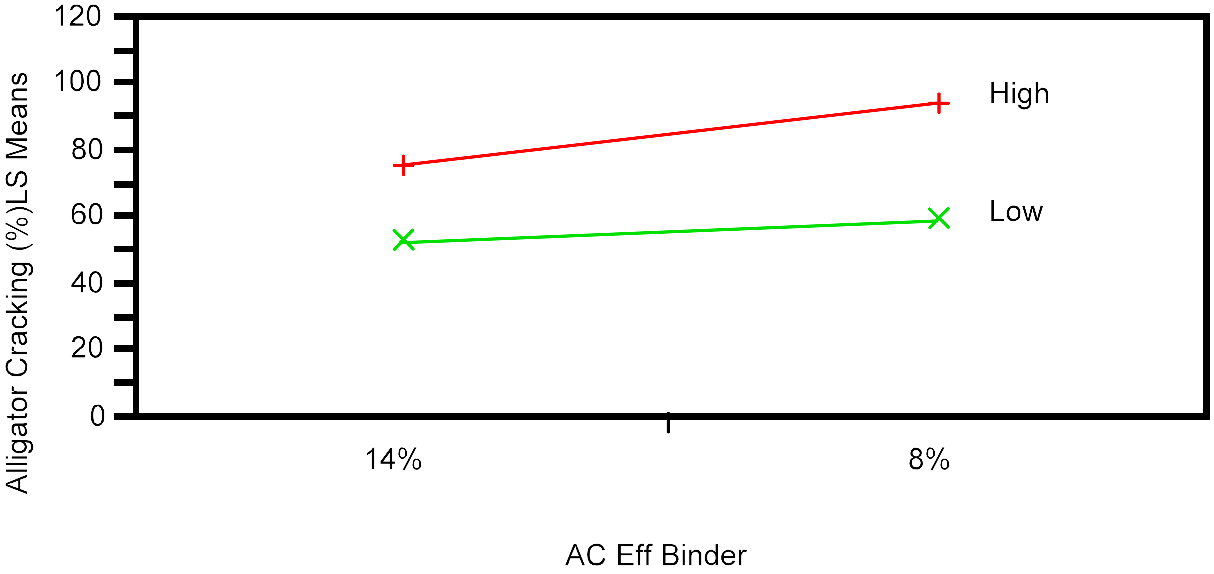

Figure O-20. Interaction Plot for CS Soil Water Value×AC Eff Binder (Alligator Cracking).

The effect of AC Eff Binder is slightly different for each level of CS Soil Water Value. In general, AC Eff Binder level 8% leads to more alligator cracking than AC Eff Binder level 14% does, regardless of the levels of CS Soil Water Value. However, the magnitude of increase in alligator cracking when AC Eff Binder level changes from 14% to 8% is slightly different for each level of CS Soil Water Value. The effect of AC Eff Binder is larger when CS Soil Water Value is High.

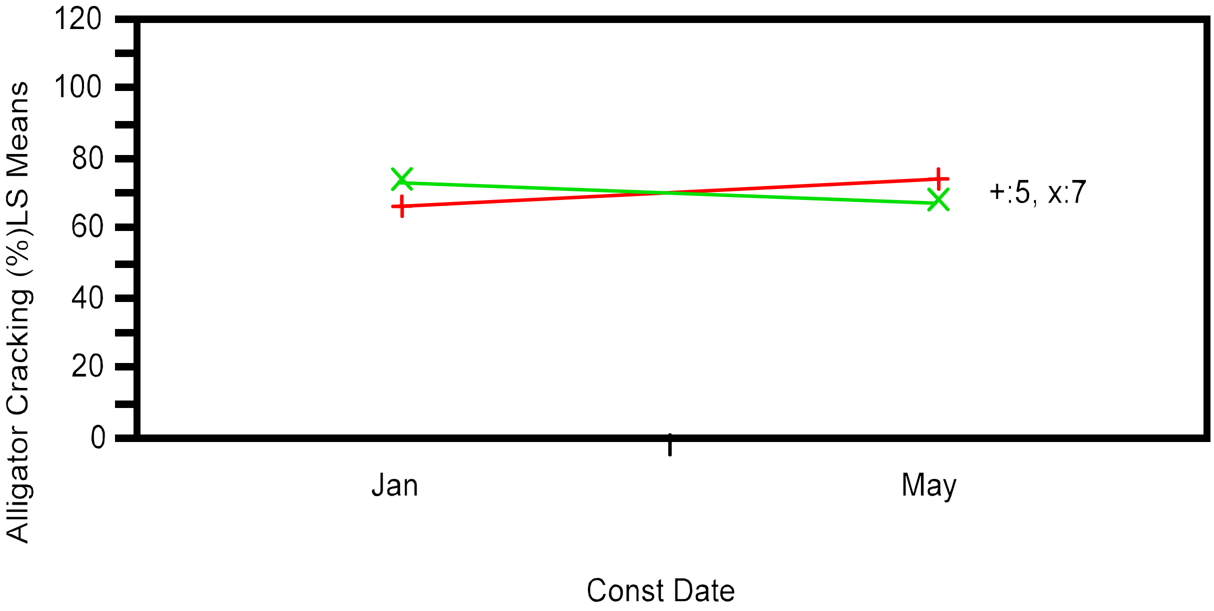

Figure O-21. Interaction Plot for CS Thick×Const Date (Alligator Cracking).

CS Thick level matters when Const Date is May, i.e., CS Thick level 7 leads to less alligator cracking than CS Thick level 5 does in May, but no statistically significant effect of CS Thick is observed when Const Date is January (the difference in mean alligator cracking values between CS Thick 5 and CS Thick 7 observed in Jan is not statistically significant, whereas the difference in May is).

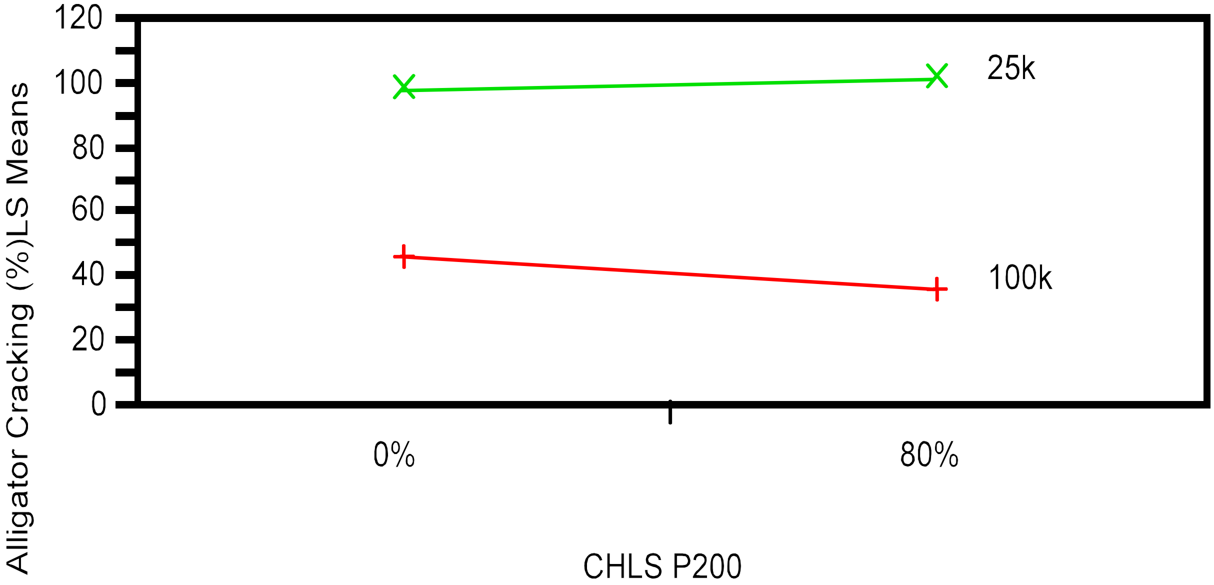

Figure O-22. Interaction Plot for CS Res Mod×CHLS P200 (Alligator Cracking).

In general, CS Res Mod 25k leads to more alligator cracking than CS Res Mod 100k does. The effect of CHLS P200 is, however, different for each level of CS Res Mod. CHLS P200 80% leads to less alligator cracking than CHLS P200 0% does when CS Res Mod is 100k, but no statistically significant effect of CHLS P200 is observed when CS Res Mod is 25k.

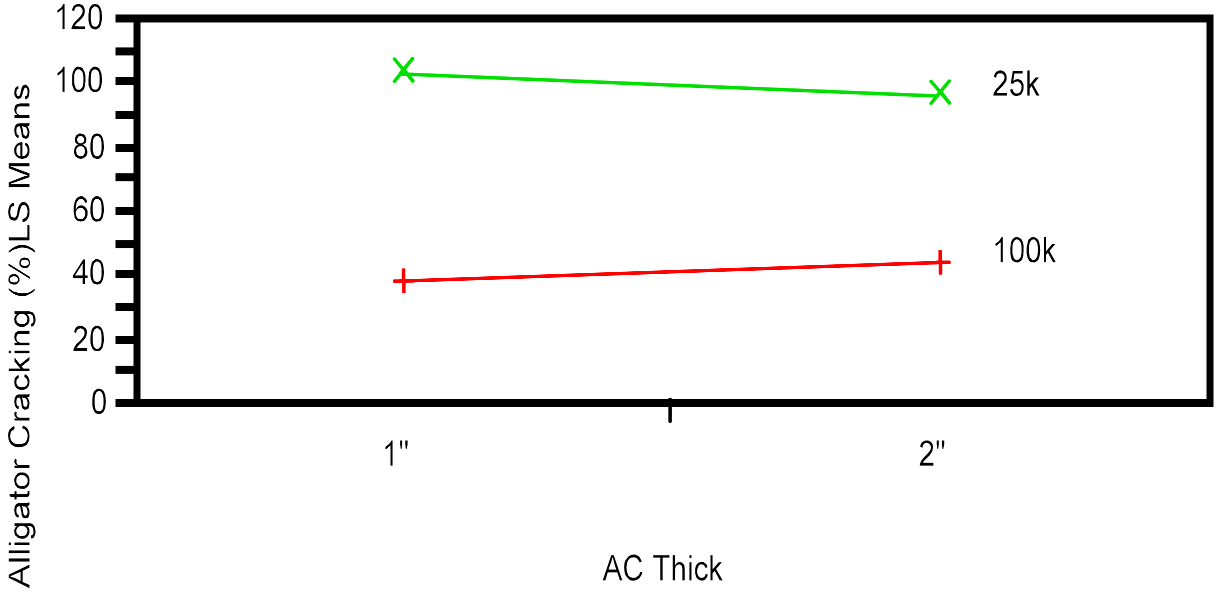

Figure O-23. Interaction Plot for CS Res Mod×AC Thick (Alligator Cracking).

In general, CS Res Mod 25k leads to more alligator cracking than CS Res Mod 100k does. The effect of AC Thick is, however, different for each level of CS Res Mod. AC Thick 2" leads to less alligator cracking than AC Thick 1" does when CS Res Mod is 25k, but no effect of AC Thick is observed when CS Res Mod is 100k.

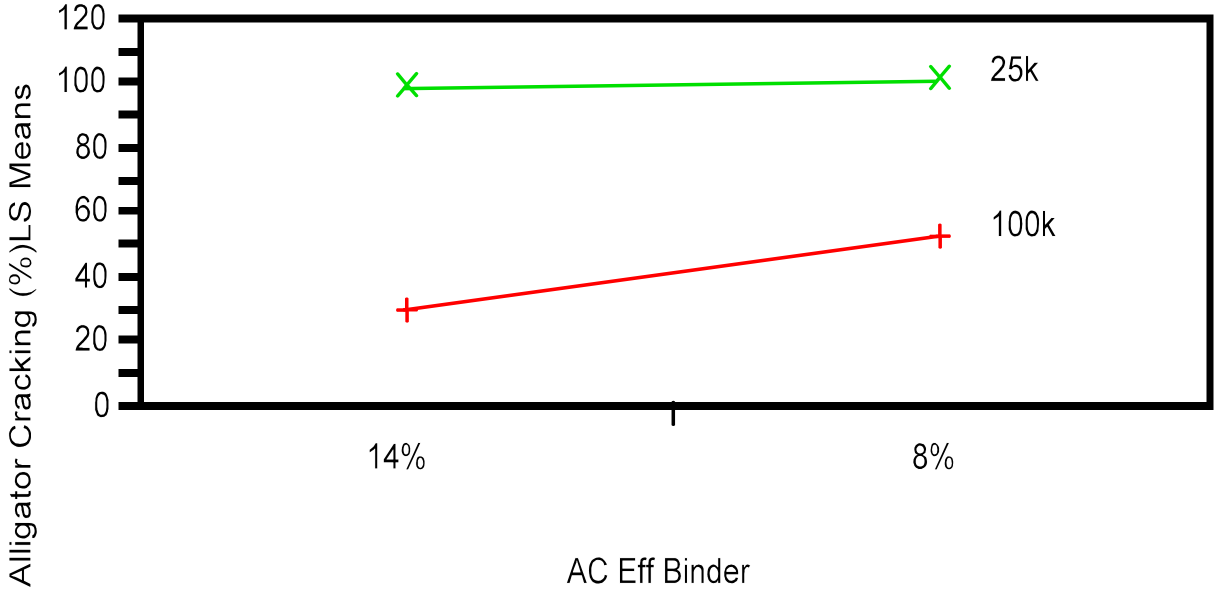

Figure O-24. Interaction Plot for CS Res Mod×AC Eff Binder (Alligator Cracking).

In general, CS Res Mod 25k leads to more alligator cracking than CS Res Mod 100k does. The effect of AC Eff Binder is, however, different for each level of CS Res Mod. AC Eff Binder 14% leads to less alligator cracking than AC Eff Binder 8% does when CS Res Mod is 100k, but AC Eff Binder does not matter when CS Res Mod is 25k.

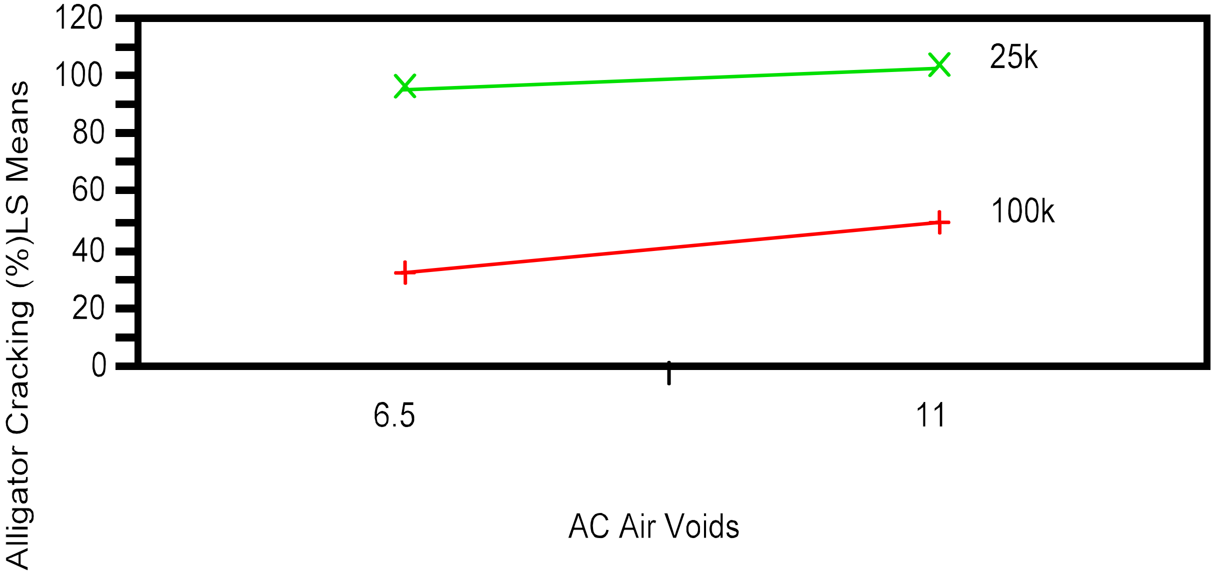

Figure O-25. Interaction Plot for CS Res Mod×AC Air Voids (Alligator Cracking).

In general, CS Res Mod 25k leads to more alligator cracking than CS Res Mod 100k does. The effect of AC Air Voids is, however, slightly different for each level of CS Res Mod. Although AC Air Voids 11 leads to more alligator cracking than AC Air Voids 6.5 does, the magnitude of increase is larger when CS Res Mod is 100k.

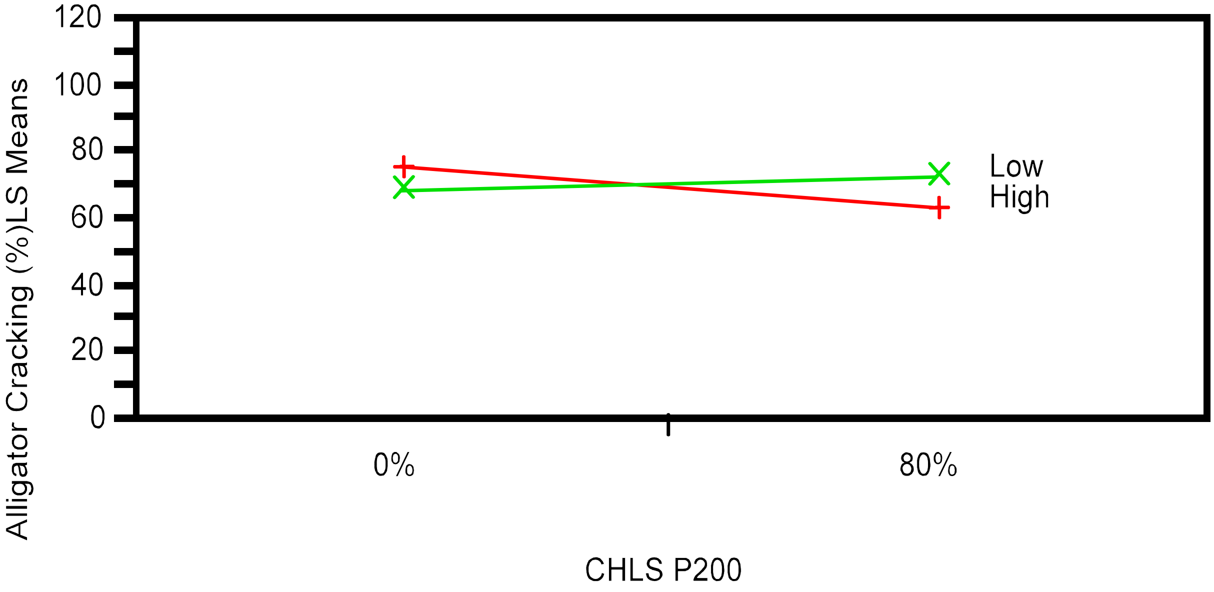

Figure O-26. Interaction Plot for CHLS Soil Water Value×CHLS P200 (Alligator Cracking).

CHLS P200 is significant for High CHLS Soil Water Value, but not for Low CHLS Soil Water Value. That is, CHLS P200 80% leads to less alligator cracking than CHLS P200 0% does when CHLS Soil Water Value is High, but no statistically significant effect of CHLS P200 is observed when CHLS Soil Water Value is Low.

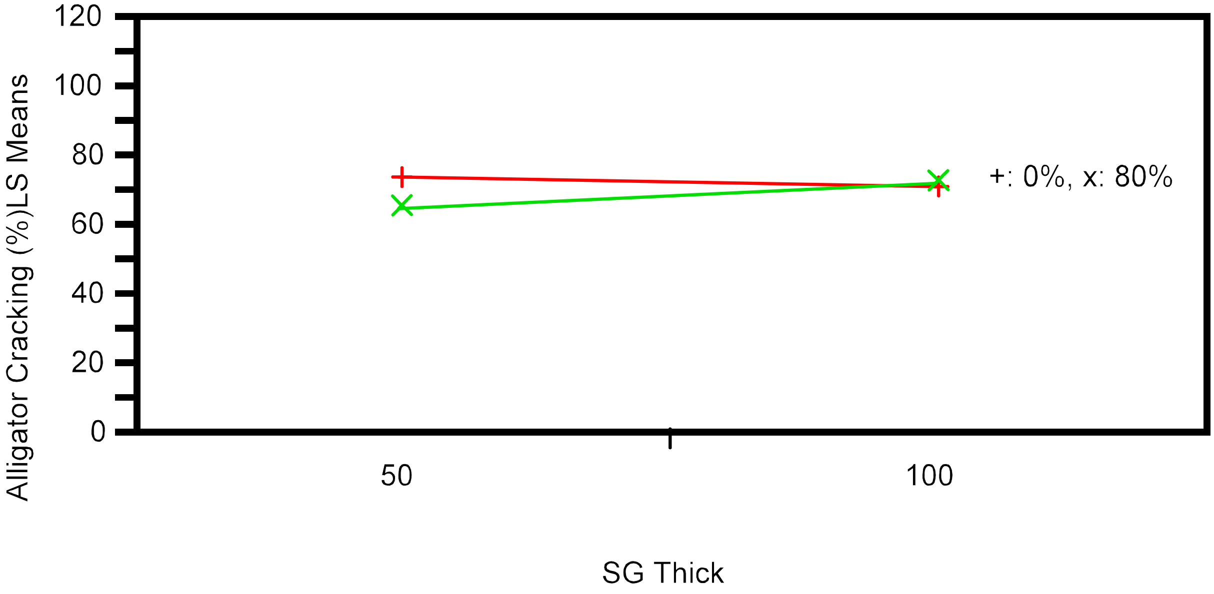

Figure O-27. Interaction Plot for CHLS P200×SG Thick (Alligator Cracking).

SG Thick matters when CHLS P200 is 80%, but not when CHLS P200 is 0%. Said another way, CHLS P200 matters for SG Thick 50, but not for SG Thick 100.

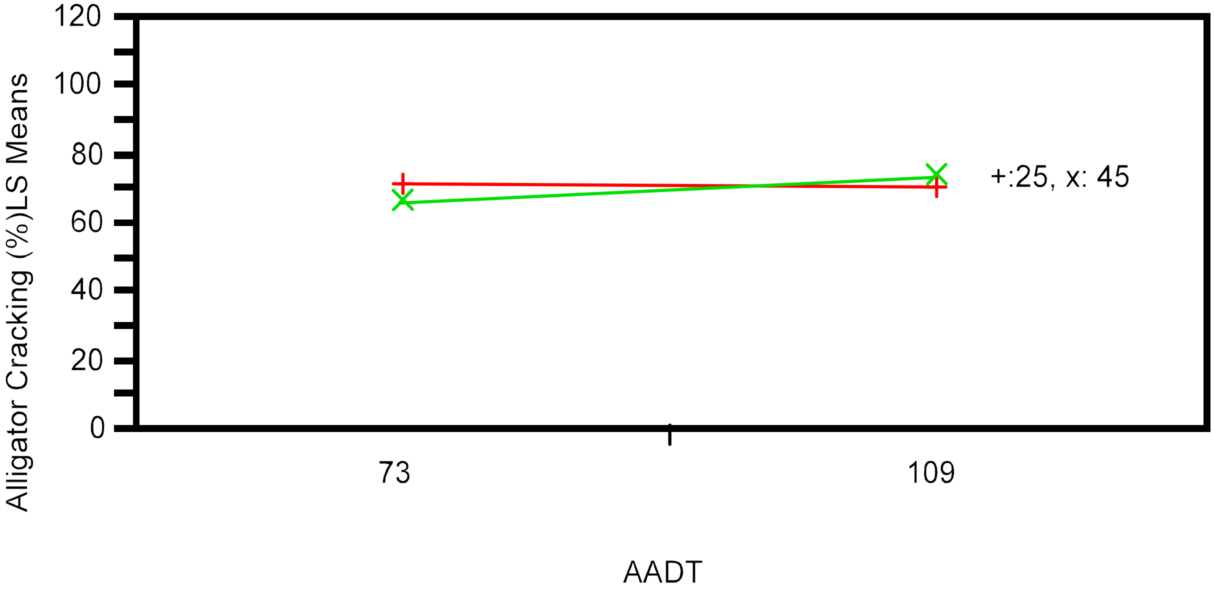

Figure O-28. Interaction Plot for CHLS Res Mod×AADT (Alligator Cracking).

AADT matters when CHLS Res Mod is 45, but not when CHLS Res Mod is 25. That is, AADT 109 leads to more alligator cracking than AADT 73 does when CHLS Res Mod is 45, but no statistically significant effect of AADT is observed when CHLS Res Mod is 25.

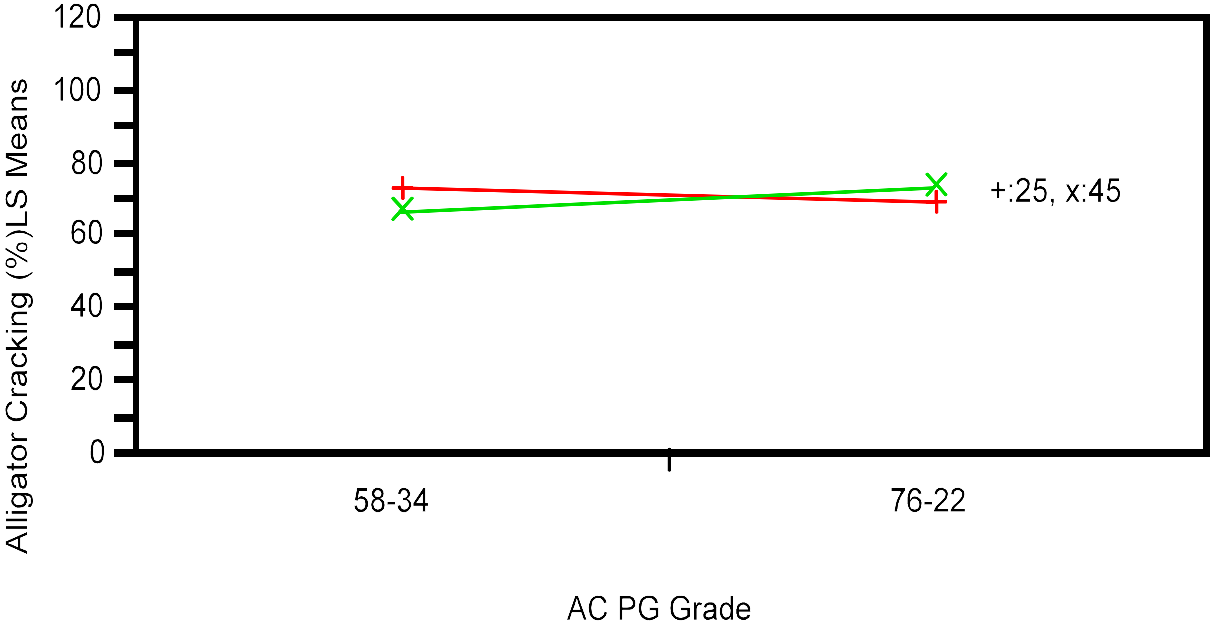

Figure O-29. Interaction Plot for CHLS Res Mod×AC PG Grade (Alligator Cracking).

AC PG Grade is significant when CHLS Res Mod is 45, but not when CHLS Res Mod is 25. That is, AC PG Grade 76-22 leads to more alligator cracking than AC PG Grade 58-34 does when CHLS Res Mod is 45, but no statistically significant effect of AC PG Grade is observed when CHLS Res Mod is 25. Said another way, CHLS Res Mod matters for AC PG Grade 58-34, but not for AC PG Grade 76-22. That is, CHLS Res Mod 25 leads to more alligator cracking than CHLS Res Mod 45 does when AC PG Grade is 58-34, but no statistically significant effect of CHLS Res Mod is observed when AC PG Grade is 76-22.

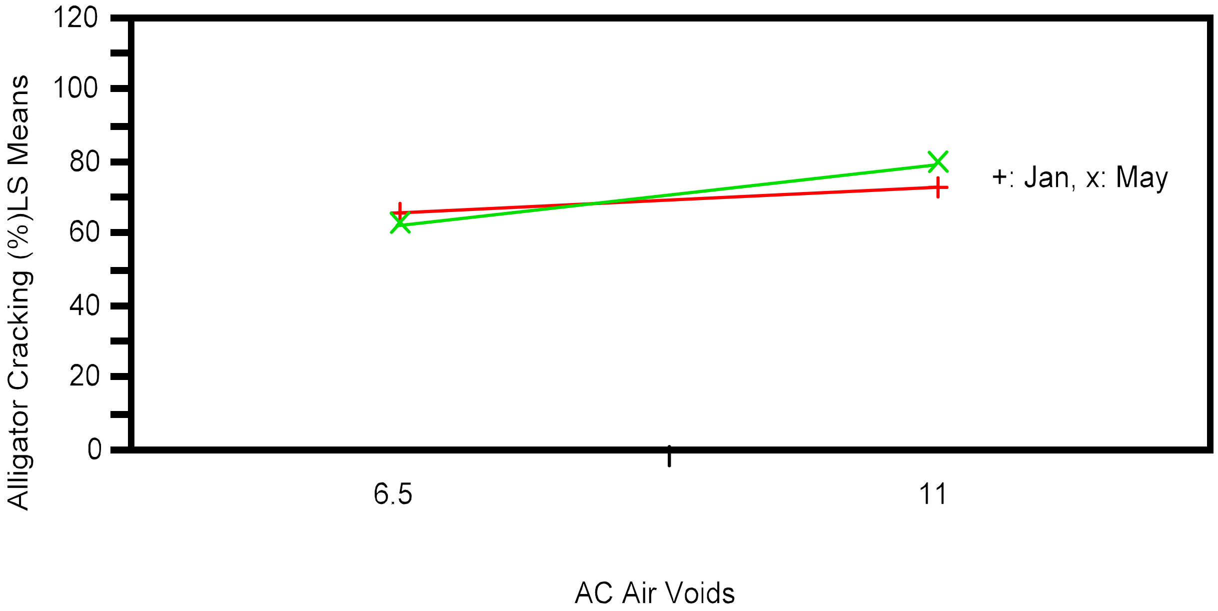

Figure 30. Interaction Plot for Const Date×AC Air Voids (Alligator Cracking).

There is not a statistically significant effect of Const Date. AC Air Voids 11 leads to more alligator cracking than AC Air Voids 6.5 does whether Const Date is January or May, although the magnitude of change is larger in May.

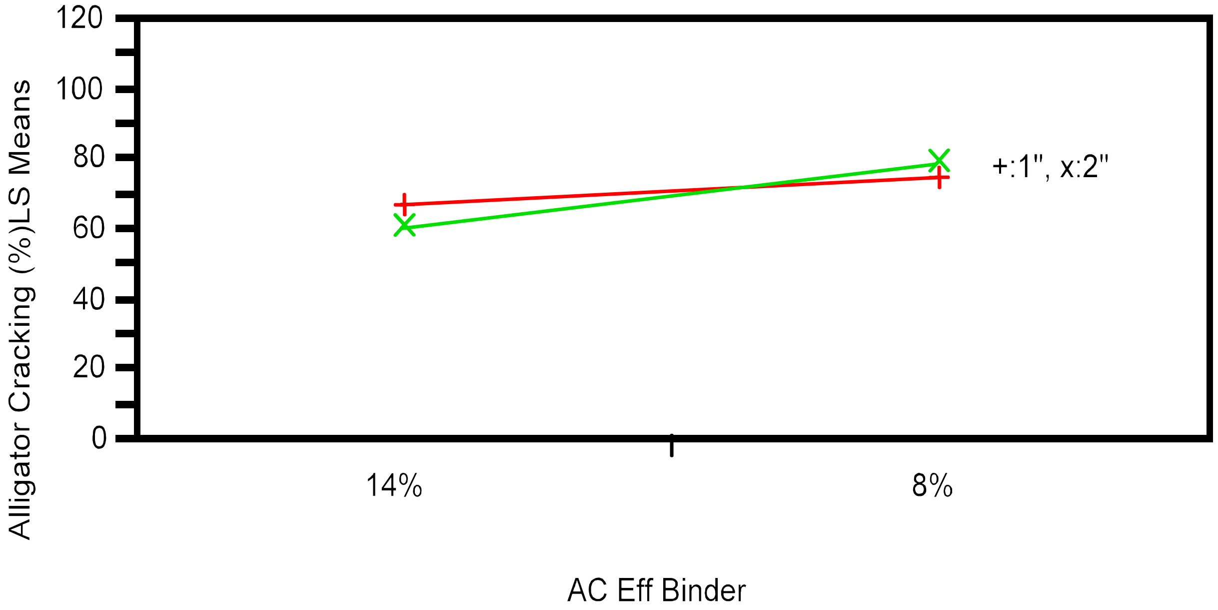

Figure O-31. Interaction Plot for AC Thick×AC Eff Binder (Alligator Cracking).

There is not a statistically significant effect of AC Thick. AC Eff Binder 8% leads to more alligator cracking than AC Eff Binder 14% does whether AC Thick is 1" or 2" although the magnitude of change is larger for 2".

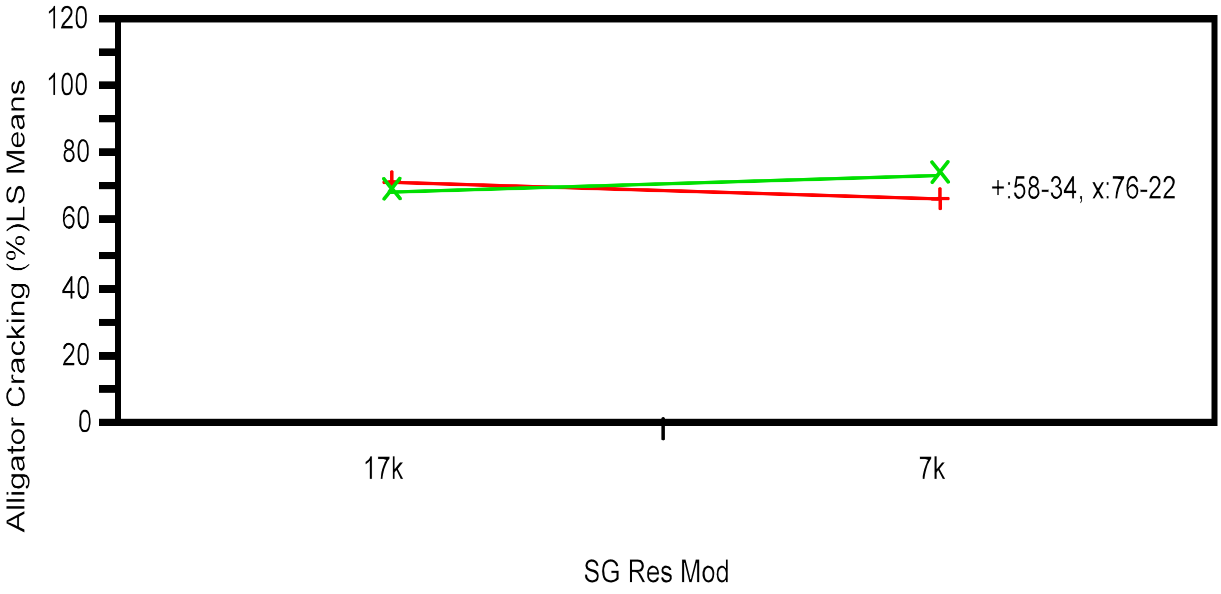

Figure O-32. Interaction Plot for AC PG Grade×SG Res Mod (Alligator Cracking).

There is not a statistically significant effect of SG Res Mod. The effect of AC PG Grade is different for different levels of SG Res Mod. When SG Res Mod is 7k, AC PG Grade 76-22 leads to more alligator cracking than AC PG Grade 58-34 does. When SG Res Mod is 17k, however, there is no statistically significant difference between AC PG Grade 76-22 and AC PG Grade 58-34.

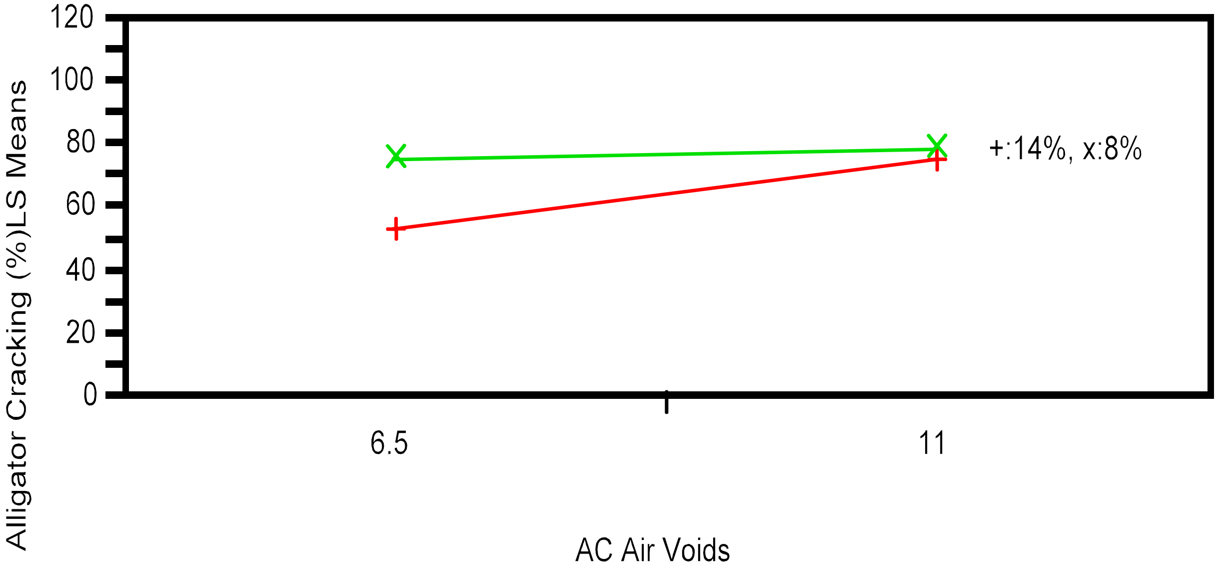

Figure O-33. Interaction Plot for AC Eff Binder×AC Air Voids (Alligator Cracking).

AC Air Voids matters for AC Eff Binder 14%, but not for AC Eff Binder 8%. AC Eff Binder matters for AC Air Voids 6.5, but not for AC Air Voids 11. Only the AC Air Voids 6.5 and AC Eff Binder 14% combination results in a statistically different alligator cracking level from the other combinations of AC Air Voids and AC Eff Binder.

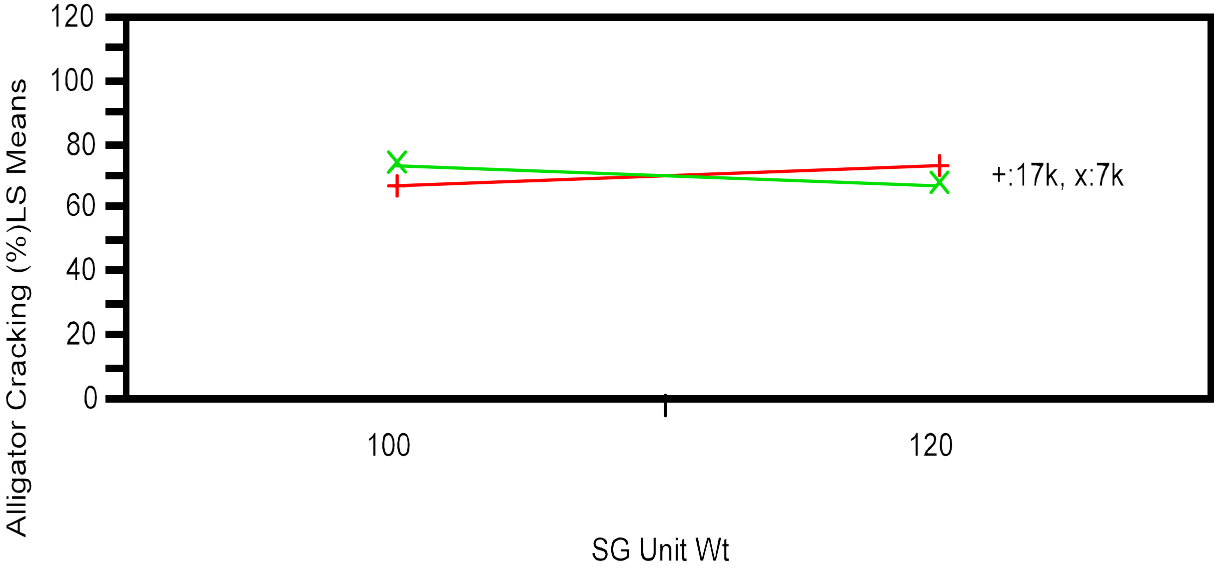

Figure O-34. Interaction Plot for SG Res Mod×SG Unit Wt (Alligator Cracking).

There is not a statistically significant effect of SG Res Mod. The effect of SG Unit Wt is different for different levels of SG Res Mod. When SG Res Mod is 17k, SG Unit Wt 120 leads to more alligator cracking than SG Unit Wt 100 does. When SG Res Mod is 7k, however, there is no statistically significant difference between SG Unit Wt 100 and SG Unit Wt 120.

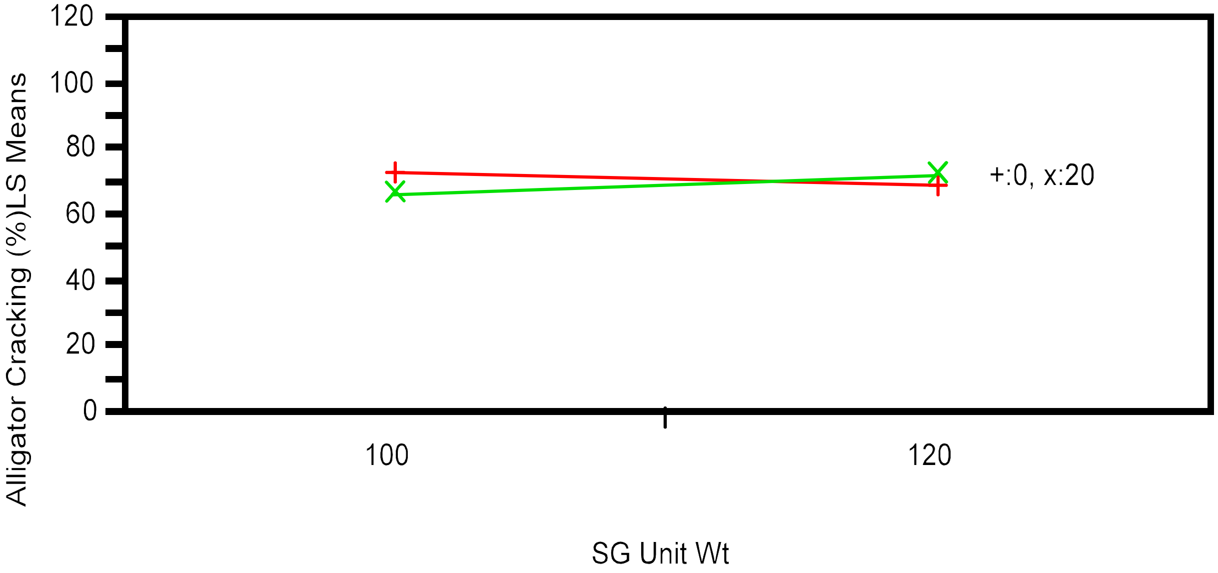

Figure O-35. Interaction Plot for SG PI×SG Unit Wt (Alligator Cracking).

There is not a statistically significant effect of SG Unit Wt. The effect of SG PI is different for different levels of SG Unit Wt. When SG Unit Wt is 100, SG PI 0 leads to more alligator cracking than SG PI 20 does. When SG Unit Wt is 120, however, there is no statistically significant difference between SG PI 0 and SG PI 20.

O.4 TRANSVERSE CRACKING

For transverse cracking, a model in Table O-4 was selected as an adequate model with respect to the terms included by a stepwise variable selection procedure. All of the 13 interaction effects retained in the model are statistically significant at the level a=0.05. For the main effects, any terms included in the significant interaction effects are retained in the model. Note that the main effects CHLS Soil Water Value, CHLS D60, CHLS P200, CHLS Res Mod, Road Type, AADT, AC Air Voids, SG PI, and SG Unit Wt are not significant by themselves and they are not part of the significant interaction effects either, and so they were excluded from the final model.

For the factors that are involved in significant interaction effects, the individual factor effects can only be assessed conditional on each level of the other factor. Plots for the statistically significant interaction effects are presented in Figures O-36 through O-48. The conclusions drawn based on those plots and the multiple comparison procedures are presented right after each plot. Multiple comparison procedures are used to determine if the differences in the average responses at different factor levels are statistically significant. For space, the tables containing the results of multiple comparison procedures are not presented here.

Table O-4. Analysis of Variance for Transverse Cracking.

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Model	22	1036.1	47.1	7.27	<.0001
CS Soil Water Value	1	89.3	89.3	13.80	0.0003
CS Thick	1	23.2	23.2	3.58	0.0604
CS Res Mod	1	0.00002	0.00002	0.00	0.9985
Const Date	1	8.6	8.6	1.33	0.2514
AC Thick	1	39.9	39.9	6.17	0.0142
AC PG Grade	1	162.3	162.3	25.07	<.0001
AC Eff Binder	1	134.0	134.0	20.70	<.0001
SG Res Mod	1	0.7	0.7	0.11	0.7369
SG Thick	1	36.1	36.1	5.57	0.0196
CS Soil Water Value×Const Date	1	39.0	39.0	6.02	0.0154
CS Soil Water Value×AC Thick	1	50.1	50.1	7.7339	0.0062
CS Soil Water Value×AC PG Grade	1	102.9	102.9	15.89	0.0001
CS Soil Water Value×AC Eff Binder	1	72.0	72.0	11.12	0.0011
CS Thick×AC PG Grade	1	50.1	50.1	7.74	0.0061
CS Thick×AC Eff Binder	1	36.7	36.7	5.67	0.0185
CS Res Mod×SG Res Mod	1	49.1	49.1	7.58	0.0067
CS Res Mod×SG Thick	1	34.1	34.1	5.27	0.0232
AC Thick×AC PG Grade	1	61.5	61.5	9.51	0.0025
AC Thick×AC Eff Binder	1	37.6	37.6	5.81	0.0172
AC PG Grade×AC Eff Binder	1	169.4	169.4	26.17	<.0001
AC PG Grade×SG Thick	1	43.9	43.9	6.79	0.0102
AC Eff Binder×SG Thick	1	67.4	67.4	10.41	0.0016
Error	141	912.8	6.5		
C. Total	163	1948.9			

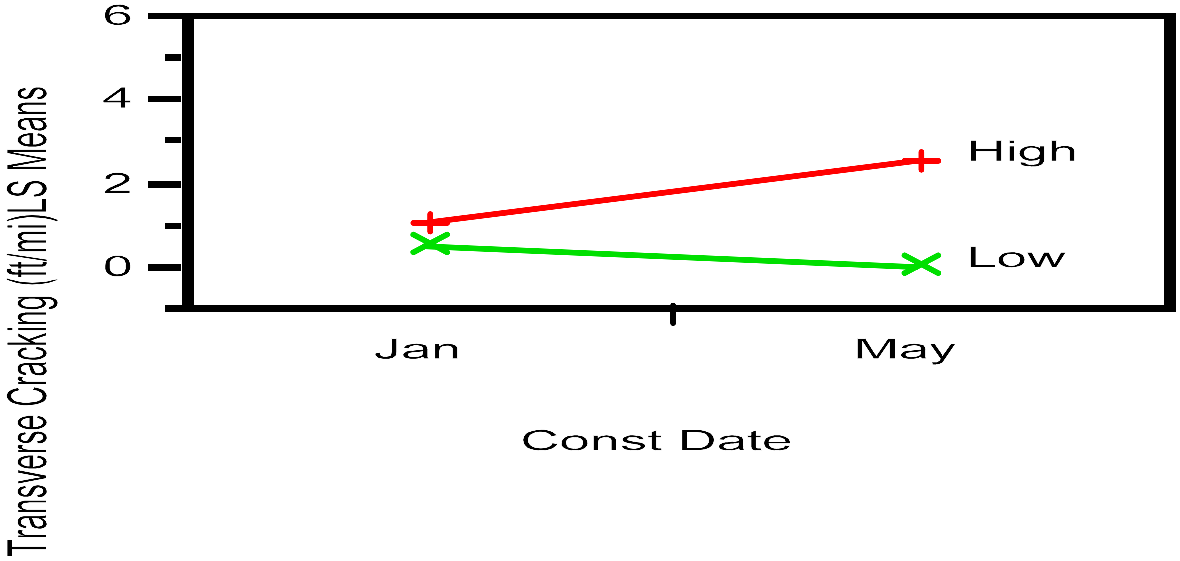

Figure O-36. Interaction Plot for CS Soil Water Value×Const Date (Transverse Cracking).

CS Soil Water Value matters when Const Date is May, i.e., CS Soil Water Value Low leads to less transverse cracking than CS Soil Water Value High does in May, but no statistically significant effect of CS Soil Water Value is observed when Const Date is January (the difference in mean transverse cracking values between CS So,il Water Value High and CS Soil Water Value Low observed in Jan is not statistically significant whereas the difference in May is).

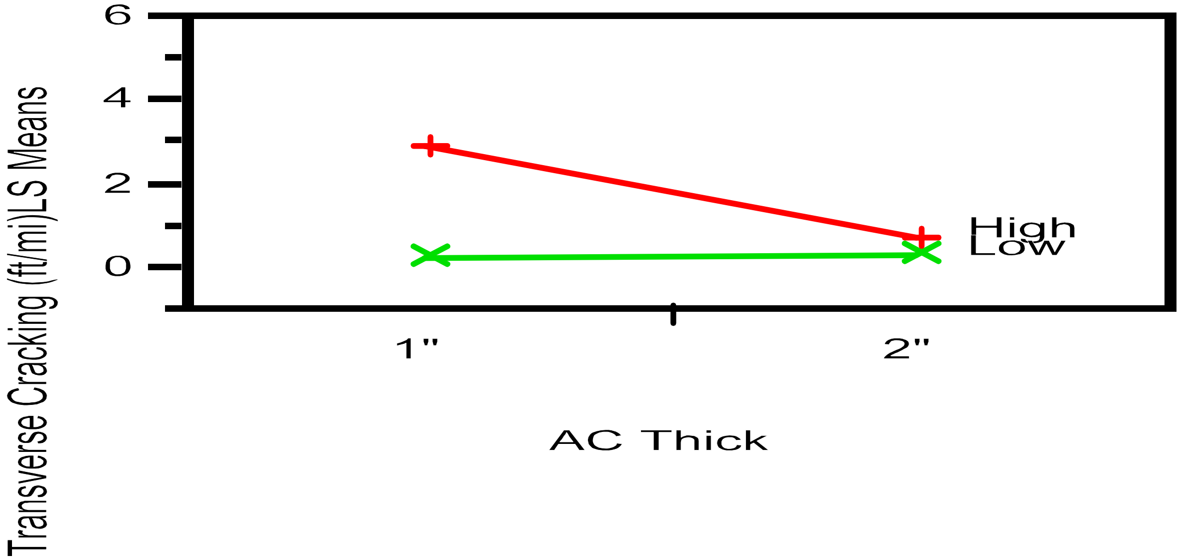

Figure O-37. Interaction Plot for CS Soil Water Value×AC Thick (Transverse Cracking).

CS Soil Water Value matters when AC Thick is 1", but not when AC Thick is 2", i.e., CS Soil Water Value Low leads to less transverse cracking than CS Soil Water Value High does for AC Thick 1", but no statistically significant effect of CS Soil Water Value is observed when AC

Thick is 2". Said another way, AC Thick matters when CS Soil Water Value is High, but not when CS Soil Water Value is Low.

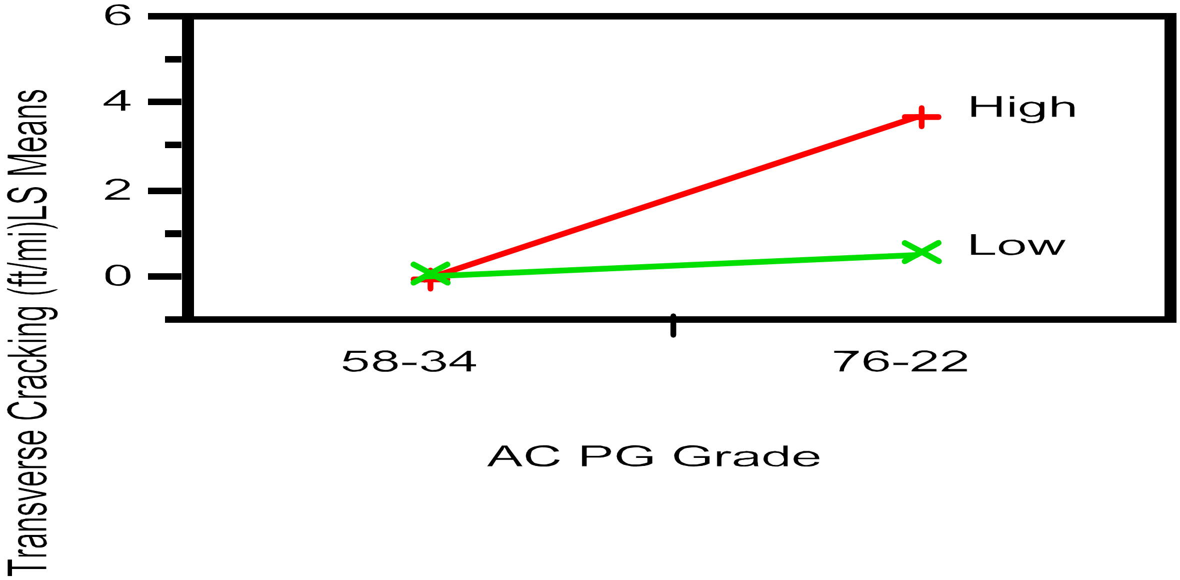

Figure O-38. Interaction Plot for CS Soil Water Value×AC PG Grade (Transverse Cracking).

CS Soil Water Value matters when AC PG Grade is 76-22, but not when AC PG Grade is 58-34 (i.e., CS Soil Water Value Low leads to less transverse cracking than CS Soil Water Value High does for AC PG Grade 76-22, but no statistically significant effect of CS Soil Water Value is observed when AC PG Grade is 58-34). Said another way, AC PG Grade matters when CS Soil Water Value is High, but not when CS Soil Water Value is Low.

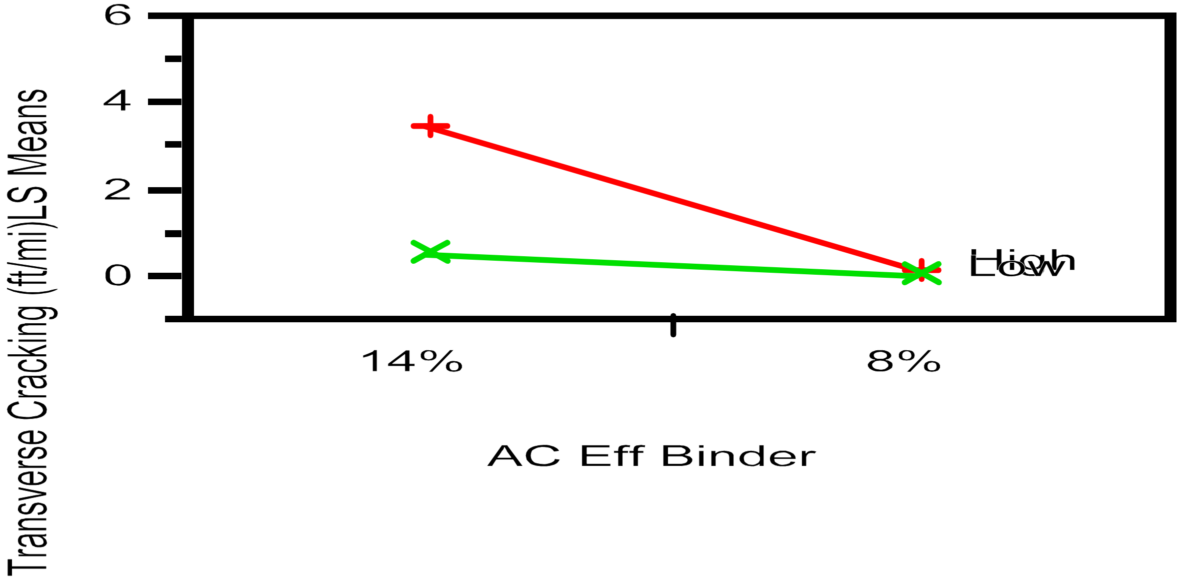

Figure O-39. Interaction Plot for CS Soil Water Value×AC Eff Binder (Transverse Cracking).

CS Soil Water Value matters when AC Eff Binder is 14%, but not when AC Eff Binder is 8%. Said another way, AC Eff Binder matters when CS Soil Water Value is High (+), but not when CS Soil Water Value is Low (x).

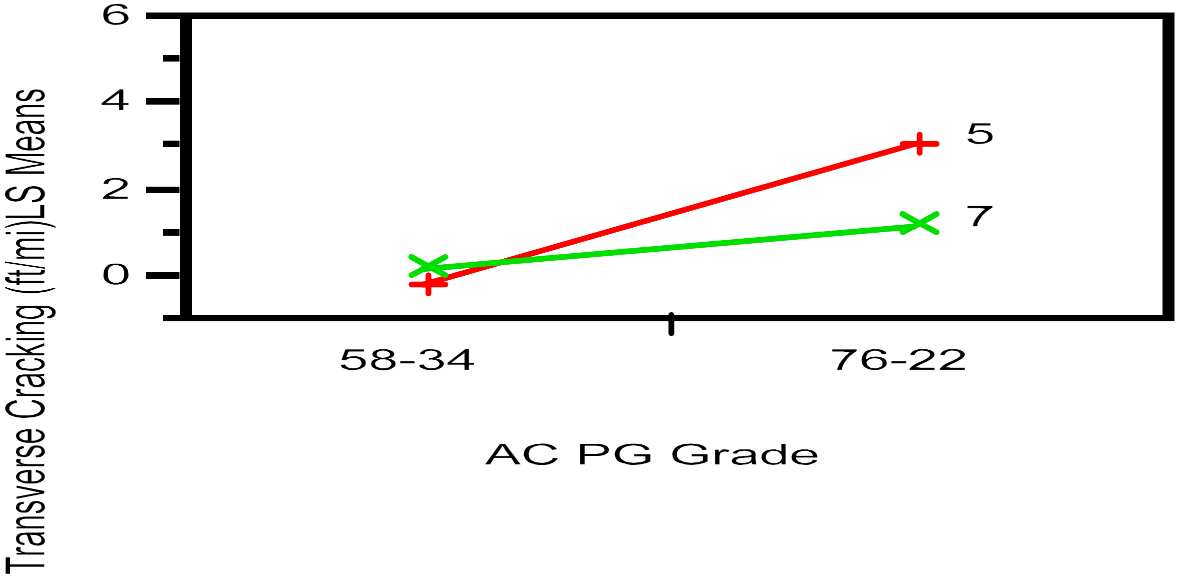

Figure O-40. Interaction Plot for CS Thick×AC PG Grade (Transverse Cracking).

CS Thick matters when AC PG Grade is 76-22, but not when AC PG Grade is 58-34 (i.e., CS Thick 7 leads to less transverse cracking than CS Thick 5 does for AC PG Grade 76-22, but no statistically significant effect of CS Thick is observed when AC PG Grade is 58-34). Said another way, AC PG Grade matters when CS Thick is 5, but not when CS Thick is 7.

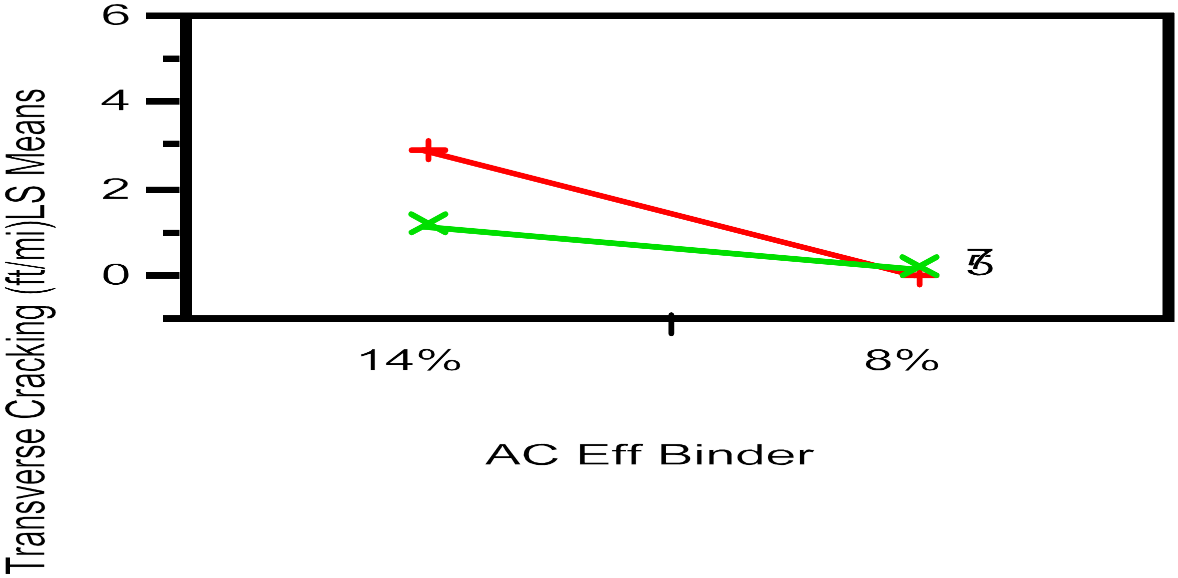

Figure O-41. Interaction Plot for CS Thick×AC Eff Binder (Transverse Cracking).

CS Thick matters when AC Eff Binder is 14%, but not when AC Eff Binder is 8% (i.e., CS Thick 7 leads to less transverse cracking than CS Thick 5 does for AC Eff Binder 14%, but no statistically significant effect of CS Thick is observed when AC Eff Binder is 8%,). Said another way, AC Eff Binder matters when CS Thick is 5 (+), but not when CS Thick is 7 (x).

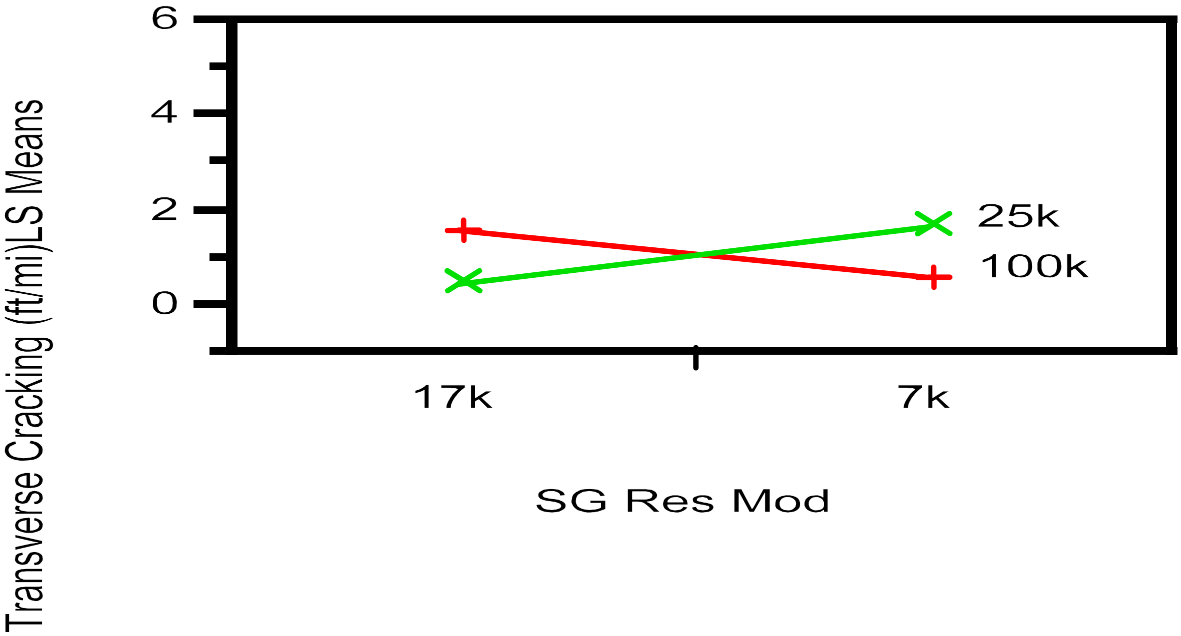

Figure O-42. Interaction Plot for CS Res Mod×SG Res Mod (Transverse Cracking).

The effect of CS Res Mod is statistically significant when SG Res Mod is 7k, but not when SG Res Mod is 17k (i.e., CS Res Mod 100k leads to less transverse cracking than CS Res Mod 25k does when SG Res Mod is 7k, but there is no statistically significant effect of CS Res Mod when SG Res Mod is 17k). Said another way, the effect of SG Res Mod is statistically significant for CS Res Mod 25k (x), but not for CS Res Mod 100k (+).

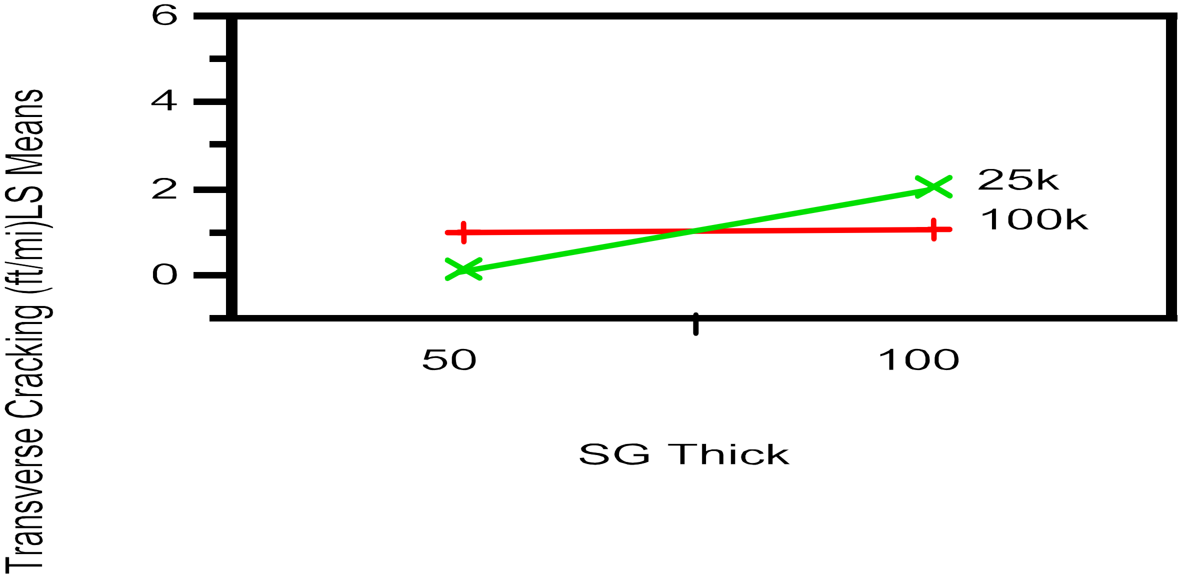

Figure O-43. Interaction Plot for CS Res Mod×SG Thick (Transverse Cracking).

The effect of SG Thick is statistically significant for CS Res Mod 25k (x), but not for CS Res Mod 100k (+) (i.e., SG Thick 50 leads to less transverse cracking than SG Thick 100 does when CS Res Mod is 25k, but there is no statistically significant effect of SG Thick when CS Res Mod is 100k). The effect of CS Res Mod is statistically insignificant whether SG Thick is 50 or 100.

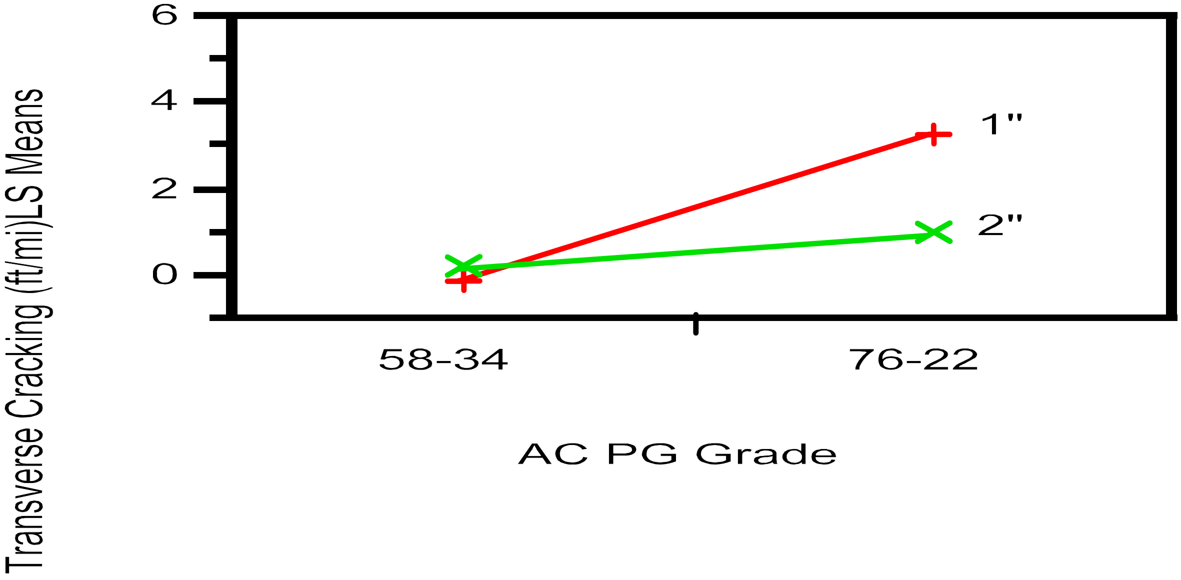

Figure O-44. Interaction Plot for AC Thick×AC PG Grade (Transverse Cracking).

AC Thick matters when AC PG Grade is 76-22, but not when AC PG Grade is 58-34 (i.e., AC Thick 2" leads to less transverse cracking than AC Thick 1" does for AC PG Grade 76-22, but no statistically significant effect of AC Thick is observed when AC PG Grade is 58-34). Said another way, AC PG Grade matters when AC Thick is 1", but not when AC Thick is 2".

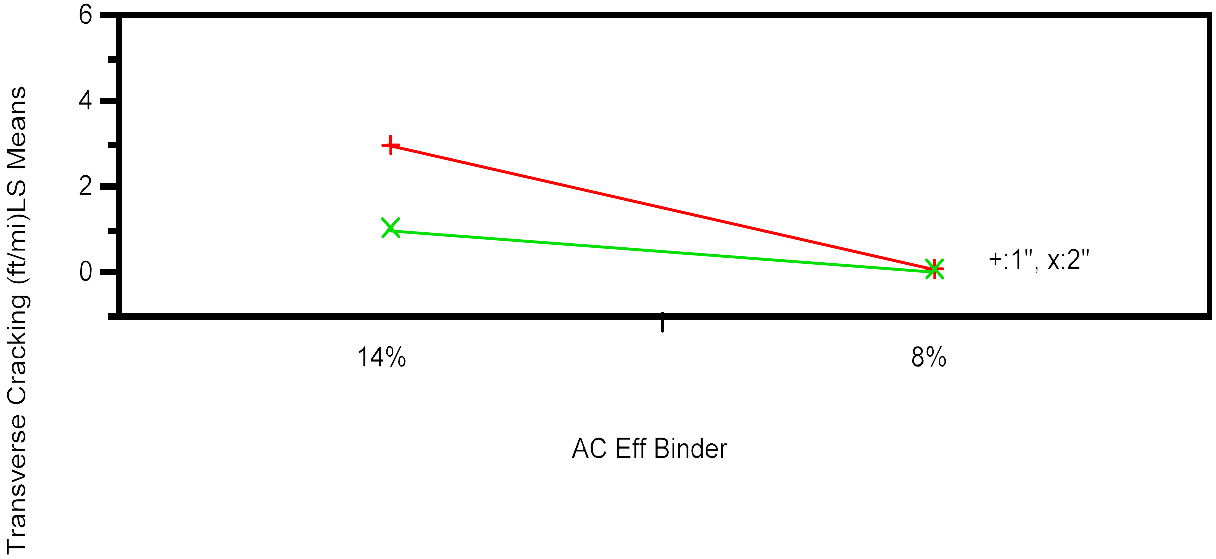

Figure O-45. Interaction Plot for AC Thick×AC Eff Binder (Transverse Cracking).

AC Thick matters when AC Eff Binder is 14%, but not when AC Eff Binder is 8% (i.e., AC Thick 2" leads to less transverse cracking than AC Thick 1" does for AC Eff Binder 14%, but no statistically significant effect of AC Thick is observed when AC Eff Binder is 8%). Said another way, AC Eff Binder matters when AC Thick is 1", but not when AC Thick is 2.

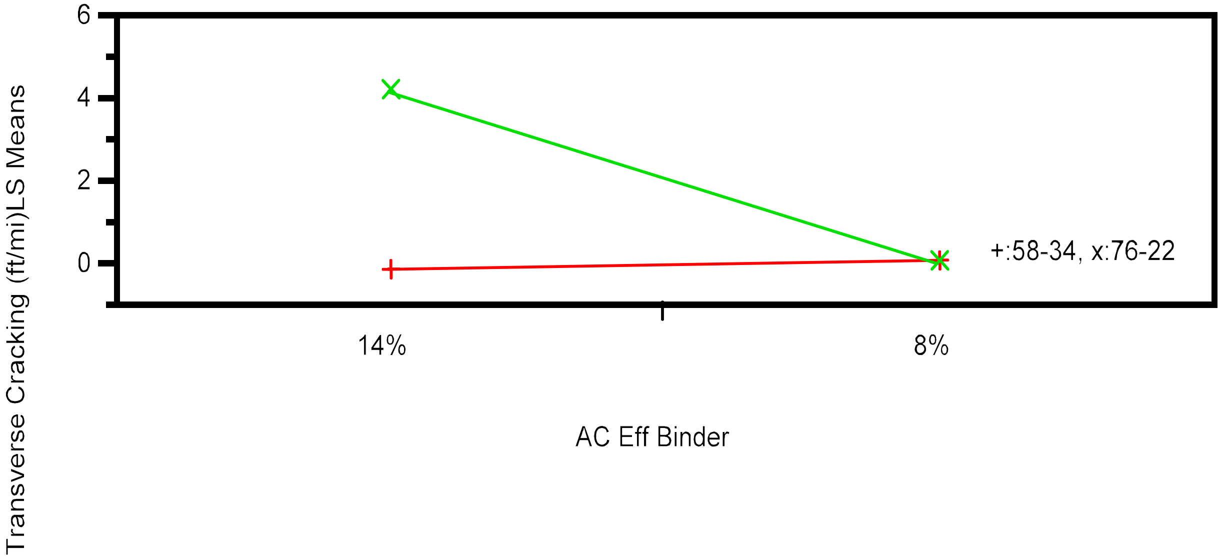

Figure O-46. Interaction Plot for AC PG Grade×AC Eff Binder (Transverse Cracking).

AC PG Grade matters when AC Eff Binder is 14%, but not when AC Eff Binder is 8% (i.e., AC PG Grade 58-34 leads to less transverse cracking than AC PG Grade 76-22 does for AC Eff Binder 14%, but no statistically significant effect of AC PG Grade is observed when AC Eff Binder is 8%). Said another way, AC Eff Binder matters when AC PG Grade is 76-22, but not when AC PG Grade is 58-34.

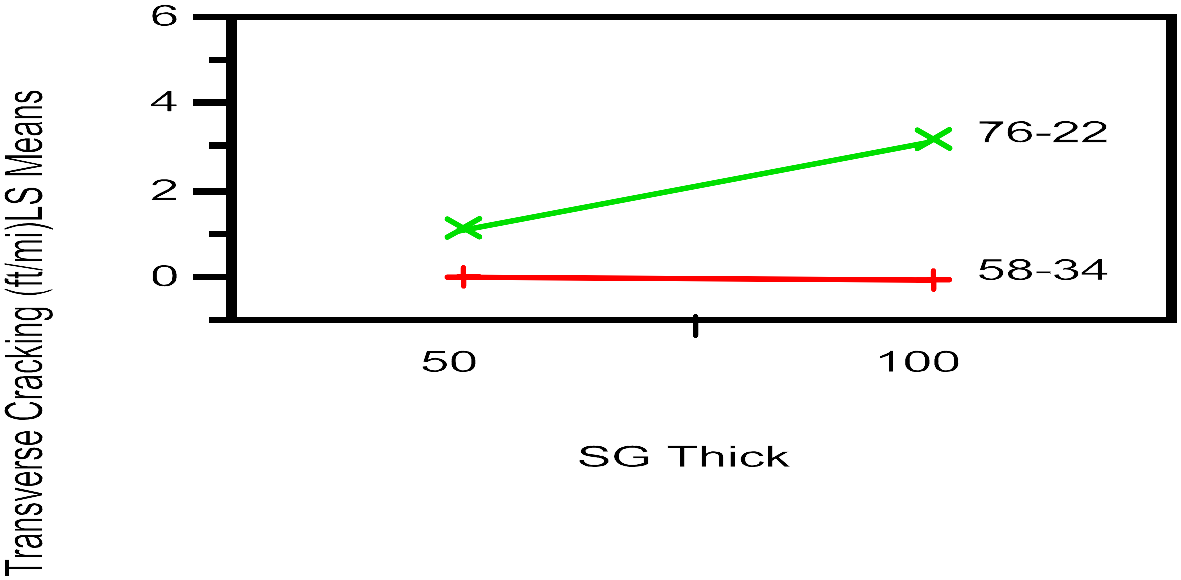

Figure O-47. Interaction Plot for AC PG Grade×SG Thick (Transverse Cracking).

AC PG Grade matters when SG Thick is 100, but not when SG Thick is 50 (i.e., AC PG Grade 58-34 leads to less transverse cracking than does AC PG Grade 76-22 for SG Thick 100, but no statistically significant effect of AC PG Grade is observed when SG Thick is 50). Said another way, SG Thick matters when AC PG Grade is 76-22, but not when AC PG Grade is 58-34.

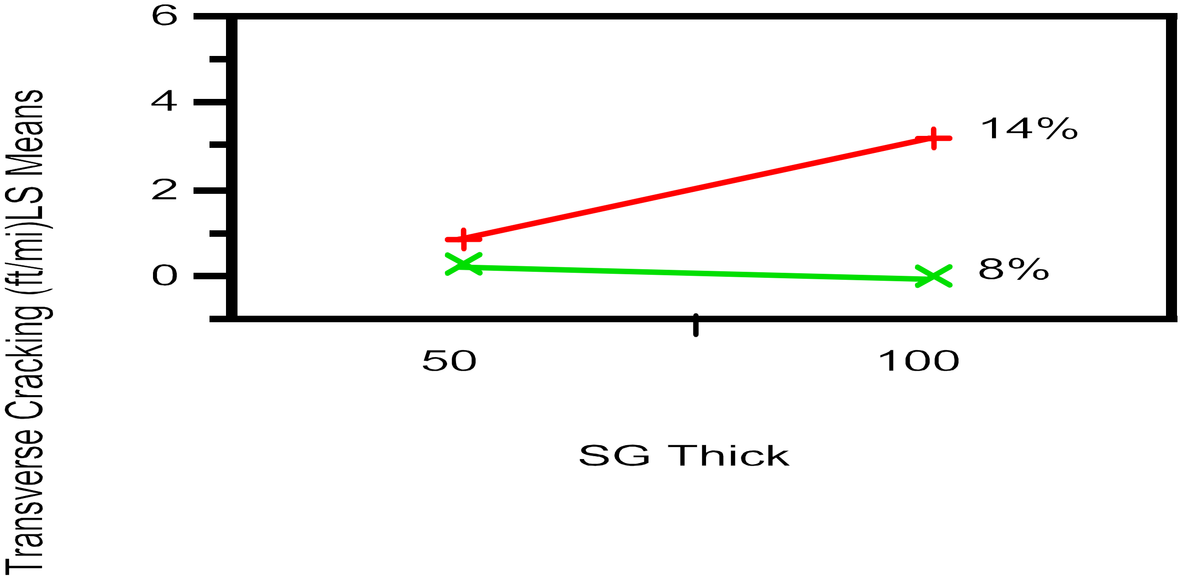

Figure O-48. Interaction Plot for AC Eff Binder×SG Thick (Transverse Cracking).

AC Eff Binder matters when SG Thick is 100, but not when SG Thick is 50 (i.e., AC Eff Binder 8% leads to less transverse cracking than AC Eff Binder 14% does for SG Thick 100, but no statistically significant effect of AC Eff Binder is observed when SG Thick is 50). Said another way, SG Thick matters when AC Eff Binder is 14%, but not when AC Eff Binder is 8%.

O.5 SUBTOTAL AC RUTTING

For subtotal AC rutting, a model in Table O-5 was selected as an adequate model with respect to the terms included by a stepwise variable selection procedure. All of the 14 interaction effects retained in the model are statistically significant at the level a=0.01. For the main effects, any terms included in the significant interaction effects are retained in the model as well as the significant main effect CHLS Soil Water Value. Note that the main effects CS Thick, CHLS D60, CHLS Res Mod, Const Date, SG Res Mod, SG PI, and SG Unit Wt are not significant by themselves and they are not part of the significant interaction effects either, and so they were excluded from the final model.

Table O-5. Analysis of Variance for Subtotal AC Rutting.

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Model	25	0.766937	0.030677	285.63	<.0001
CS Soil Water Value	1	0.016289	0.016289	151.66	<.0001
CS Res Mod	1	0.054045	0.054050	503.24	<.0001
CHLS Soil Water Value	1	0.001311	0.001311	12.21	0.0006
CHLS P200	1	0.000840	0.000840	7.82	0.0059
Road Type	1	0.002397	0.002397	22.32	<.0001
AADT	1	0.007643	0.007643	71.16	<.0001
AC Thick	1	0.405789	0.405789	3778.17	<.0001
AC PG Grade	1	0.031057	0.031057	289.16	<.0001
AC Eff Binder	1	0.011069	0.011069	103.06	<.0001
AC Air Voids	1	0.017731	0.017731	165.09	<.0001
SG Thick	1	0.003426	0.003426	31.90	<.0001
CS Soil Water Value×CS Res Mod	1	0.002323	0.002323	21.63	<.0001
CS Soil Water Value×CHLS P200	1	0.001862	0.001862	17.34	<.0001
CS Soil Water Value×AC Thick	1	0.005859	0.005859	54.55	<.0001
CS Soil Water Value×AC PG Grade	1	0.000888	0.000888	8.27	0.0047
CS Res Mod×CHLS P200	1	0.001164	0.001164	10.84	0.0013
CS Res Mod×AC Thick	1	0.015307	0.015307	142.52	<.0001
Road Type×AC Thick	1	0.001669	0.001669	15.54	0.0001
AADT×AC Thick	1	0.003341	0.003341	31.11	<.0001
AC Thick×AC PG Grade	1	0.021324	0.021324	198.54	<.0001
AC Thick×AC Eff Binder	1	0.008058	0.008058	75.03	<.0001
AC Thick×AC Air Voids	1	0.012954	0.012954	120.61	<.0001
AC Thick×SG Thick	1	0.001265	0.001265	11.78	0.0008
AC Eff Binder×AC Air Voids	1	0.001178	0.001178	10.97	0.0012
AC Eff Binder×SG Thick	1	0.001238	0.001238	11.52	0.0009
Error	138	0.014822	0.000107		
C. Total	163	0.781759			

For the factors that are involved in significant interaction effects, the individual factor effects can only be assessed conditional on each level of the other factor. The main effect of CHLS Soil Water Value can be assessed because it does not interact with any other factors. Figure O-50 contains the least squares means plot for CHLS Soil Water Value. It can be concluded from the plot that CHLS Soil Water Value High leads to less subtotal AC rutting than CHLS Soil Water Value Low does.

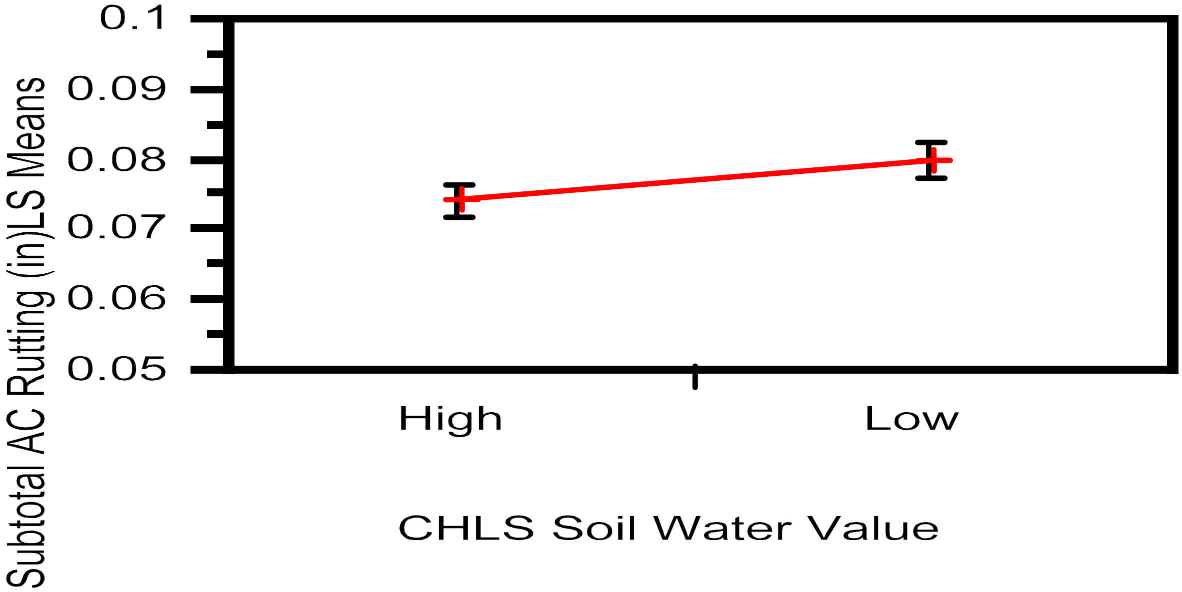

Figure O-49. Least Squares Means Plot for CHLS Soil Water Value.

Plots for the statistically significant interaction effects are presented in Figures O-50 through O-63. The conclusions drawn based on those plots and the multiple comparison procedures are presented right after each plot. Multiple comparison procedures are used to determine if the differences in the average responses at different factor levels are statistically significant. For space, the tables containing the results of multiple comparison procedures are not presented here.

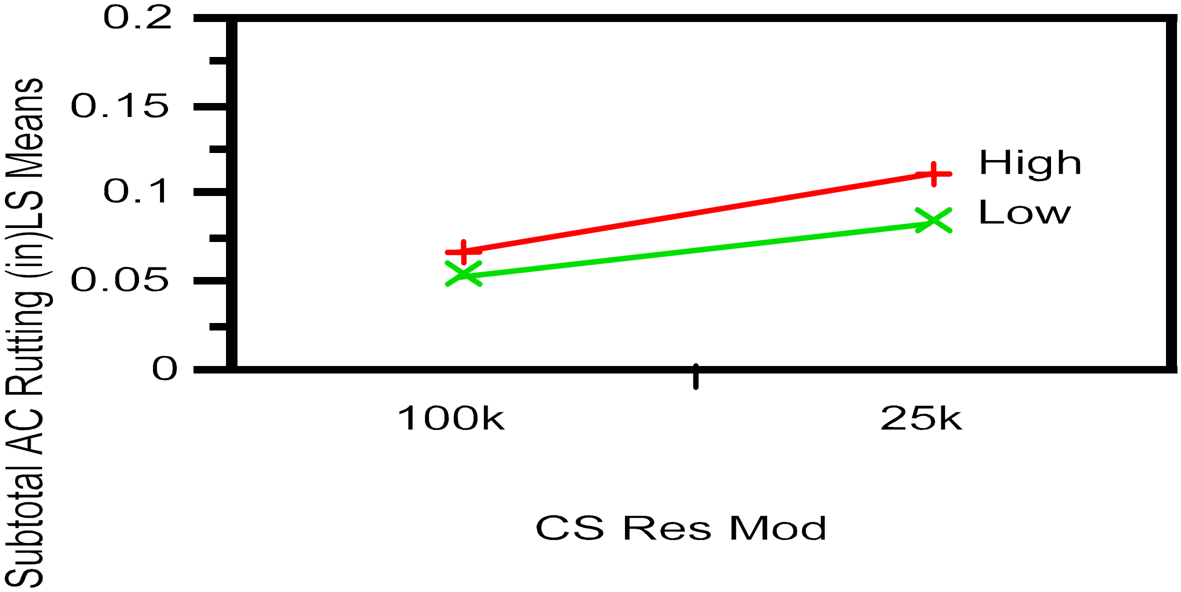

Figure O-50. Interaction Plot for CS Soil Water Value×CS Res Mod (Subtotal AC Rutting).

In general, CS Soil Water Value High leads to more subtotal AC rutting than CS Soil Water Value Low does. The magnitude of increase in subtotal AC rutting when CS Soil Water value changes from Low to High is slightly larger for CS Res Mod 25k than for CS Res Mod 100k.

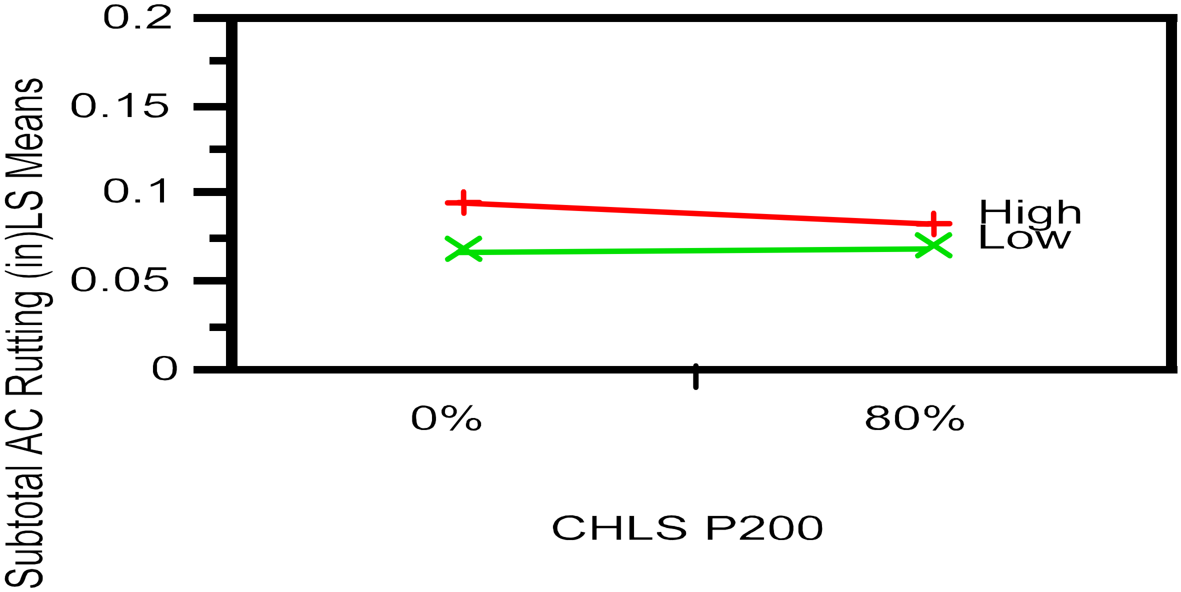

Figure O-51. Interaction Plot for CS Soil Water Value×CHLS P200 (Subtotal AC Rutting).

In general, CS Soil Water Value High leads to more subtotal AC rutting than CS Soil Water Value Low does. CHLS P200 matters when CS Soil Water Value is High, but not when CS Soil Water Value is Low.

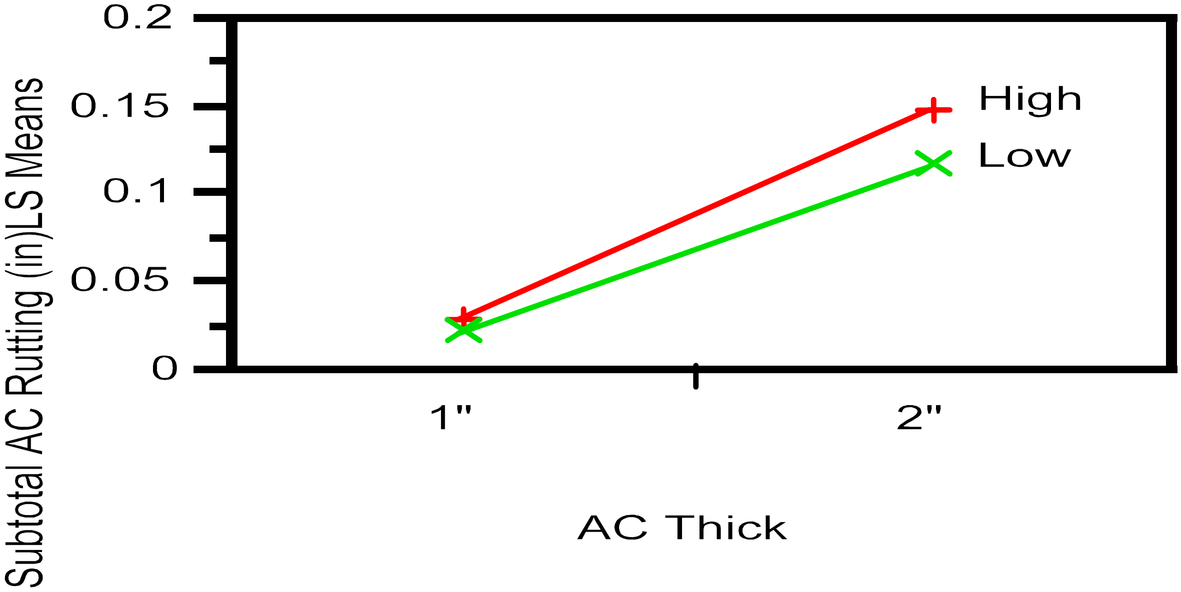

Figure O-52. Interaction Plot for CS Soil Water Value×AC Thick (Subtotal AC Rutting).

In general, AC Thick 2" leads to more subtotal AC rutting than AC Thick 1" does, and CS Soil Water Value High leads to more subtotal AC rutting than CS Soil Water Value Low does. The magnitude of increase depends on the level of the other factor.

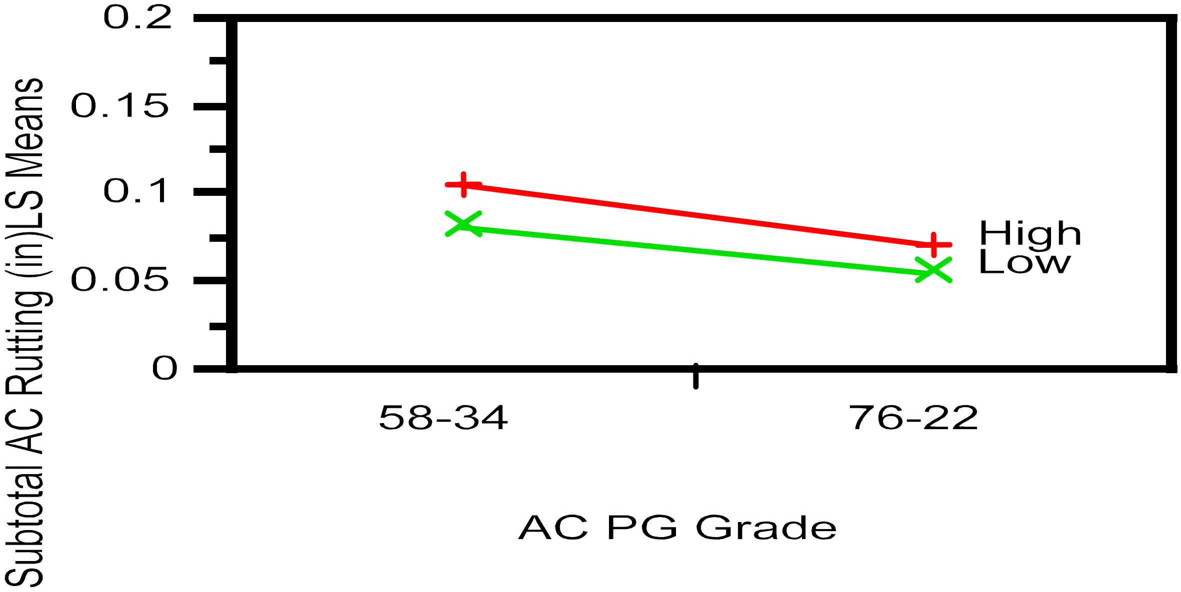

Figure O-53. Interaction Plot for CS Soil Water Value×AC PG Grade (Subtotal AC Rutting).

In general, AC PG Grade 58-34 leads to more subtotal AC rutting than AC PG Grade 76-22 does, and CS Soil Water Value High leads to more subtotal AC rutting than CS Soil Water Value Low does. The magnitude of increase depends on the level of the other factor.

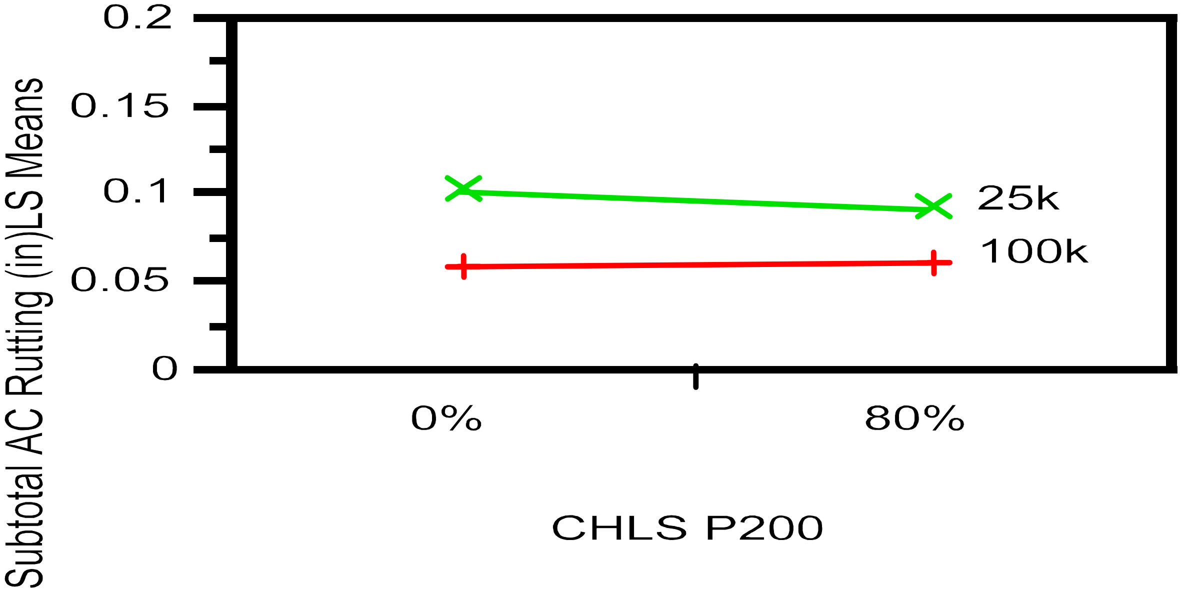

Figure O-54. Interaction Plot for CS Res Mod×CHLS P200 (Subtotal AC Rutting).

CHLS P200 matters when CS Res Mod is 25k, but not when CS Res Mod is 100k. In general, CS Res Mod 25k leads to more subtotal AC rutting than CS Res Mod 100k does, although the magnitude of increase is slightly different for each level of CHLS P200.

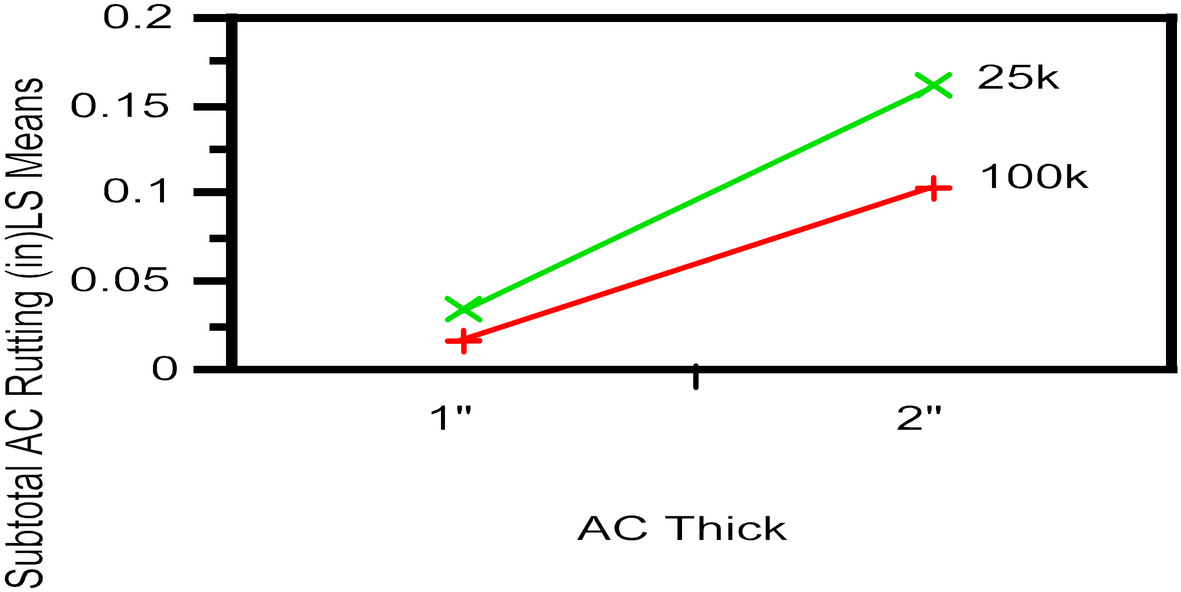

Figure O-55. Interaction Plot for CS Res Mod×AC Thick (Subtotal AC Rutting).

In general, AC Thick 2" leads to more subtotal AC rutting than AC Thick 1" does, and CS Res Mod 25k leads to more subtotal AC rutting than CS Res Mod 100k does. The magnitude of increase is slightly different for each level of the other factor.

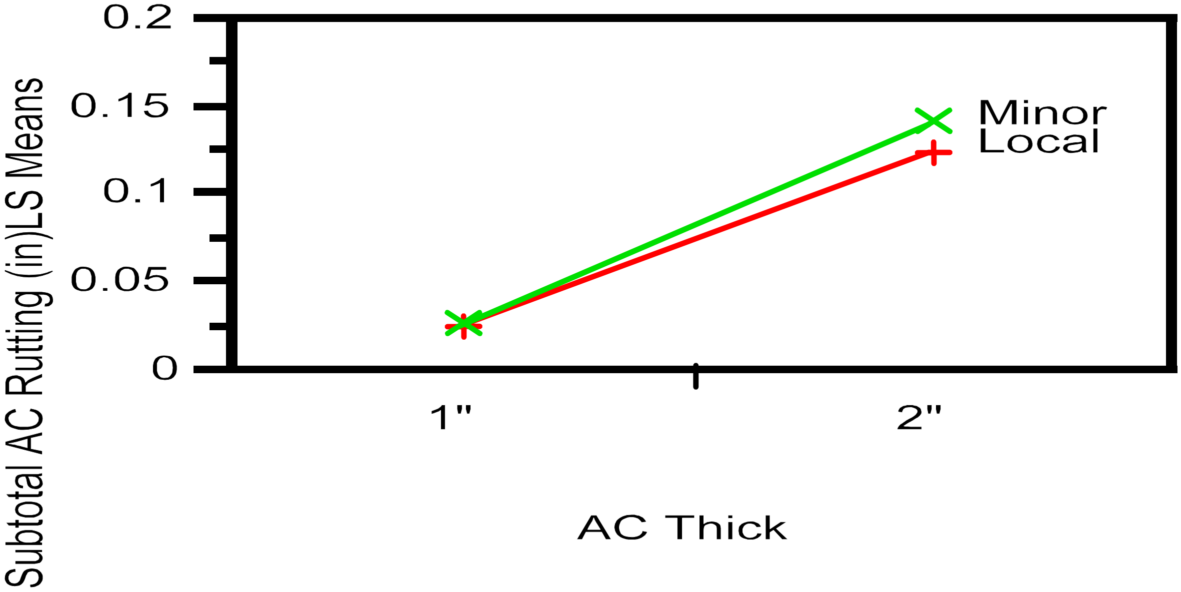

Figure O-56. Interaction Plot for Road Type×AC Thick (Subtotal AC Rutting).

Road Type matters when AC Thick is 2", but not when AC Thick is 1". In general, AC Thick is 2" leads to more subtotal AC rutting than AC Thick is 1" does, although the magnitude of increase is slightly larger for Minor Road.

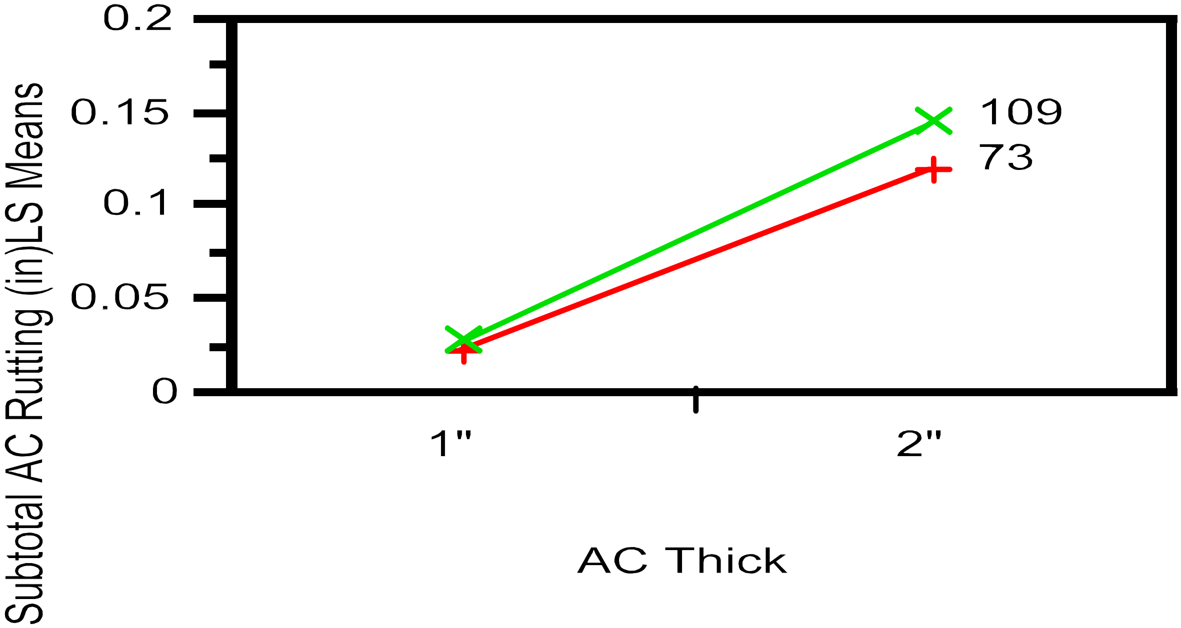

Figure O-57. Interaction Plot for AADT×AC Thick (Subtotal AC Rutting).

AADT matters when AC Thick is 2", but not when AC Thick is 1". In general, AC Thick is 2" leads to more subtotal AC rutting than AC Thick is 1" does, although the magnitude of increase is slightly larger when AADT is 109.

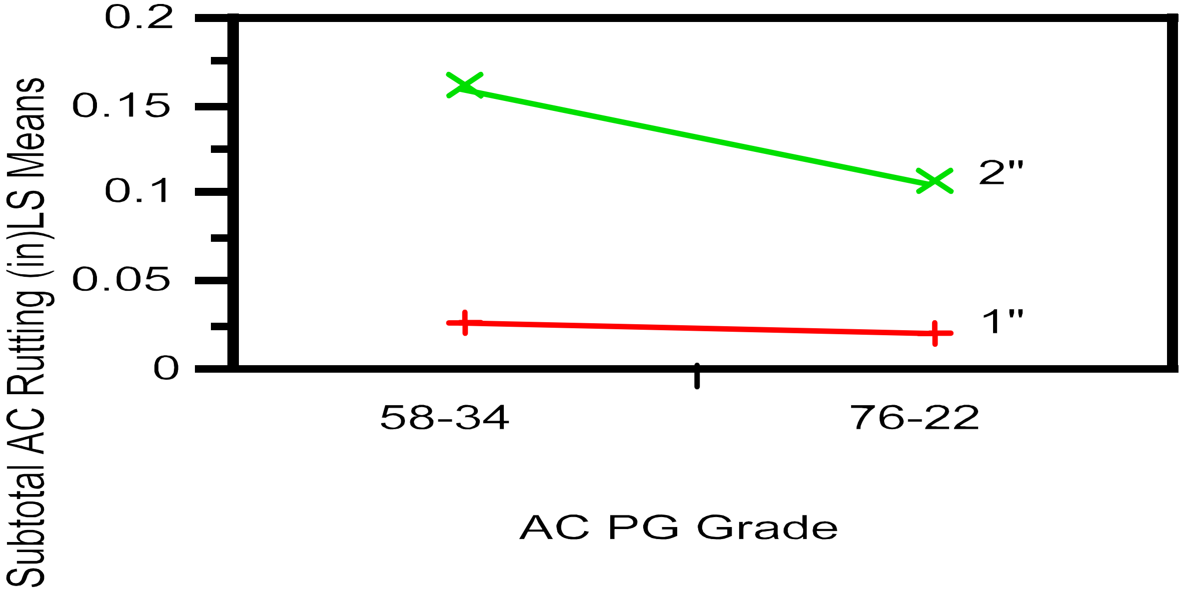

Figure O-58. Interaction Plot for AC Thick×AC PG Grade (Subtotal AC Rutting).

AC PG Grade matters when AC Thick is 2", but not when AC Thick is 1". In general, AC Thick 2" leads to more subtotal AC rutting than AC Thick is 1" does, although the magnitude of increase in subtotal AC rutting (as AC Thick changes from 1" to 2") is larger for AC PG Grade 58-34.

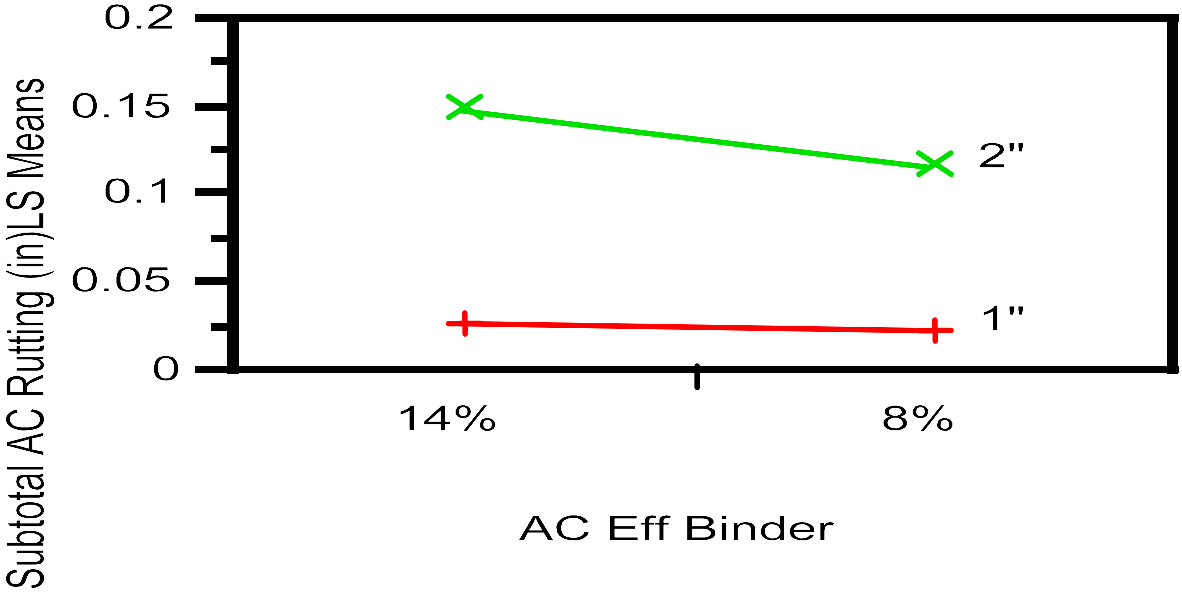

Figure O-59. Interaction Plot for AC Thick×AC Eff Binder (Subtotal AC Rutting).

AC Eff Binder matters when AC Thick is 2", but not when AC Thick is 1". In general, AC Thick is 2" leads to more subtotal AC rutting than AC Thick 1" does although the magnitude of increase in subtotal AC rutting (as AC Thick changes from 1" to 2") is larger for AC Eff Binder 14%.

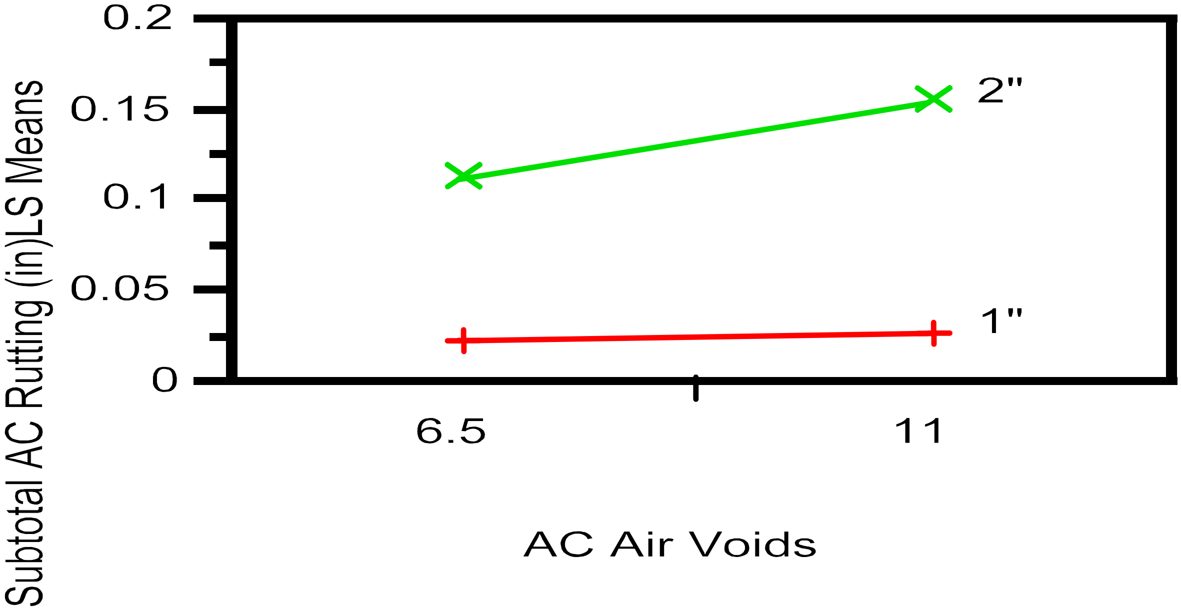

Figure O-60. Interaction Plot for AC Thick×AC Air Voids (Subtotal AC Rutting).

AC Air Voids matters when AC Thick is 2", but not when AC Thick is 1". In general, AC Thick 2" leads to more subtotal AC rutting than AC Thick 1" does although the magnitude of increase in subtotal AC rutting (as AC Thick changes from 1" to 2") is larger when AC Air Voids is 11.

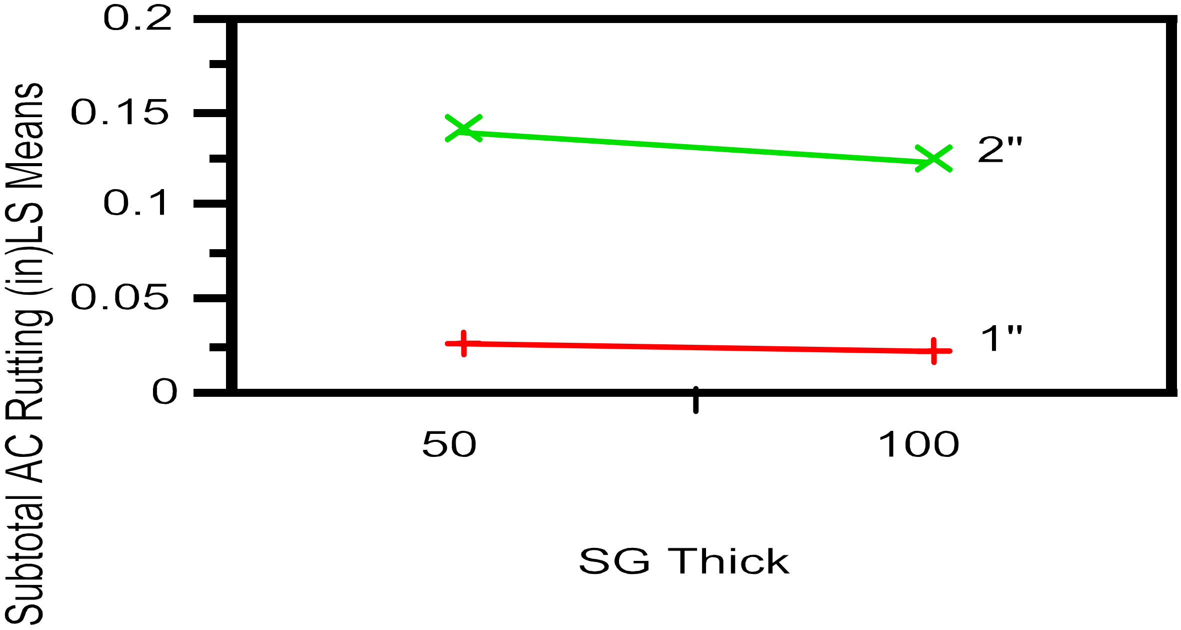

Figure O-61. Interaction Plot for AC Thick×SG Thick (Subtotal AC Rutting).

SG Thick matters when AC Thick is 21, but not when AC Thick is 1". In general, AC Thick 2" leads to more subtotal AC rutting than AC Thick 1" does.

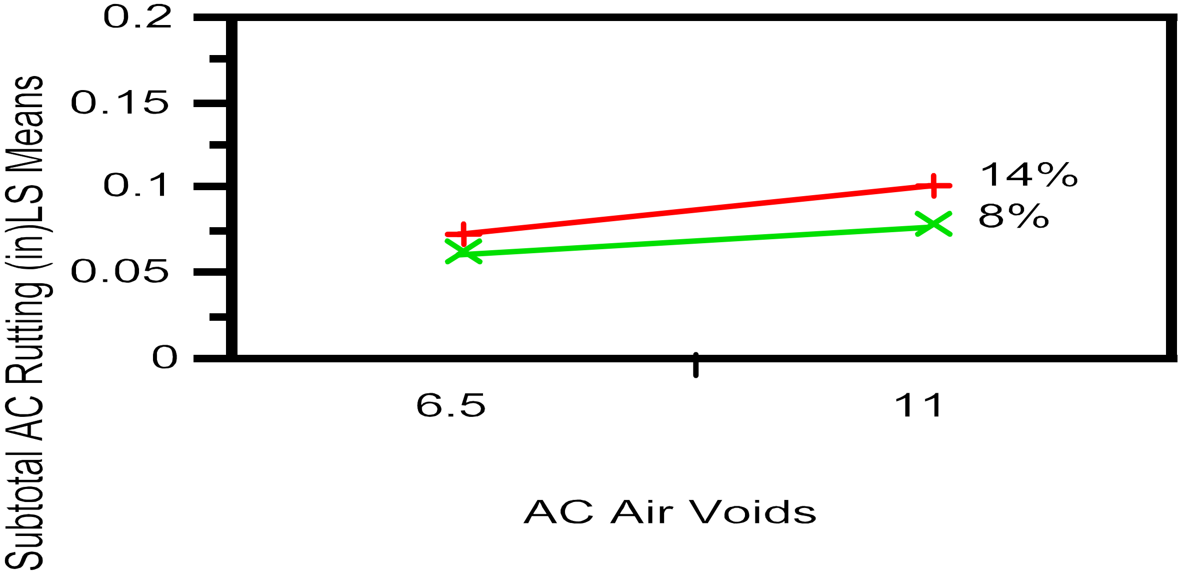

Figure O-62. Interaction Plot for AC Eff Binder×AC Air Voids (Subtotal AC Rutting).

In general, AC Air Voids 11 leads to more subtotal AC rutting than AC Air Voids 6.5 does, and AC Eff Binder 14% leads to more subtotal AC rutting than AC Eff Binder 8% does. The magnitude of increase is slightly different for each level of the other factor.

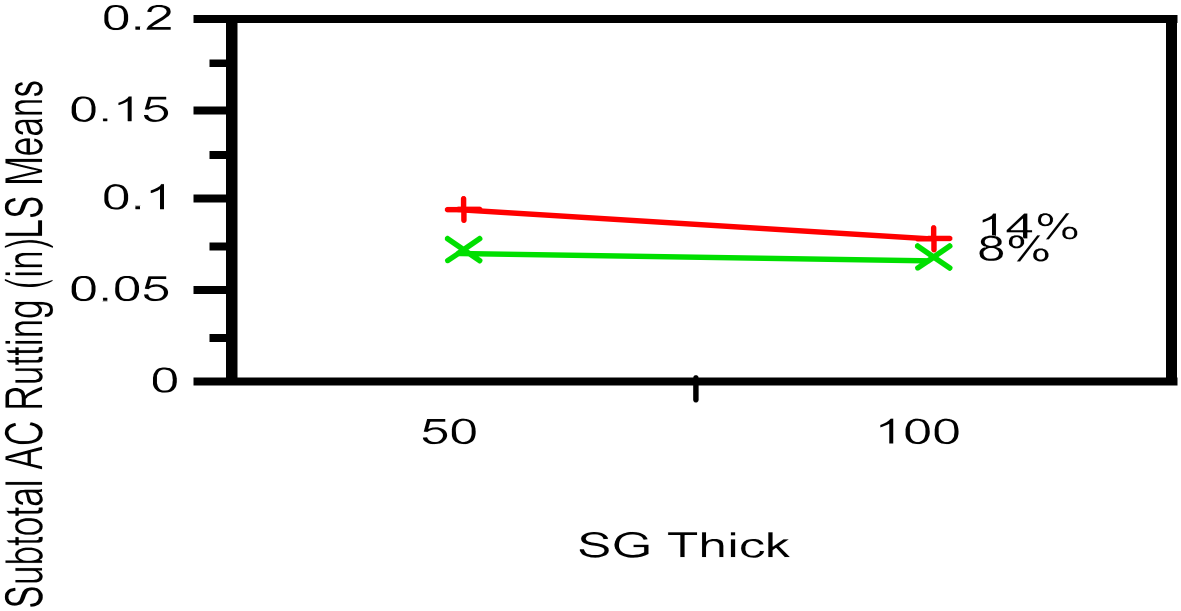

Figure O-63. Interaction Plot for AC Eff Binder×SG Thick (Subtotal AC Rutting).

SG Thick matters when AC Eff Binder is 14%, but not when AC Eff Binder is 8%. In general, AC Eff Binder 14% leads to more subtotal AC rutting than AC Eff Binder 8% does.

O.6 TOTAL RUTTING

For total rutting, the model in Table O-6 was selected as an adequate model with respect to the terms included by a stepwise variable selection procedure. All of the 11 interaction effects retained in the model are statistically significant at the level a=0.01. For the main effects, any terms included in the significant interaction effects are retained in the model as well as the significant main effects CS Thick, CHLS Res Mod, Road Type, SG Res Mod, SG PI, and SG Unit Wt. Note that the main effects CHLS D60 and Const Date are not significant by themselves and they are not part of the significant interaction effects either, and so they were excluded from the final model.

Table O-6. Analysis of Variance for Total Rutting.

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Model	27	0.948935	0.035146	142.28	<.0001
CS Soil Water Value	1	0.070506	0.070506	285.42	<.0001
CS Thick	1	0.023659	0.023659	95.77	<.0001
CS Res Mod	1	0.238128	0.238128	963.99	<.0001
CHLS Soil Water Value	1	0.000212	0.000212	0.86	0.3559
CHLS P200	1	0.009992	0.009992	40.45	<.0001
CHLS Res Mod	1	0.002207	0.002207	8.93	0.0033
Road Type	1	0.012462	0.012462	50.45	<.0001
AADT	1	0.055561	0.055561	224.92	<.0001
AC Thick	1	0.085286	0.085286	345.25	<.0001
AC PG Grade	1	0.050113	0.050113	202.87	<.0001
AC Eff Binder	1	0.016391	0.016391	66.35	<.0001
AC Air Voids	1	0.026088	0.026088	105.61	<.0001
SG Res Mod	1	0.040684	0.040684	164.70	<.0001
SG Thick	1	0.115462	0.115462	467.41	<.0001
SG PI	1	0.023634	0.023634	95.67	<.0001
SG Unit Wt	1	0.002707	0.002707	10.96	0.0012
CS Soil Water Value×CS Res Mod	1	0.004131	0.004131	16.72	<.0001
CS Soil Water Value ×CHLS Soil Water Value	1	0.001784	0.001784	7.22	0.0081
CS Soil Water Value×CHLS P200	1	0.005905	0.005905	23.91	<.0001
CS Res Mod×AC Thick	1	0.004963	0.004963	20.09	<.0001
CS Res Mod×AC PG Grade	1	0.002485	0.002485	10.06	0.0019
CHLS Soil Water Value×CHLS P200	1	0.007227	0.007227	29.26	<.0001
AADT×AC Thick	1	0.005504	0.005504	22.28	<.0001
AC Thick×AC PG Grade	1	0.020850	0.020850	84.41	<.0001
AC Thick×AC Eff Binder	1	0.007181	0.007181	29.07	<.0001
AC Thick×AC Air Voids	1	0.012151	0.012151	49.19	<.0001
AC Thick×SG Thick	1	0.002473	0.002473	10.01	0.0019
Error	136	0.033595	0.000247		
C. Total	163	0.982531			

For the factors that are involved in significant interaction effects, the individual factor effects can only be assessed conditional on each level of the other factor. The main effects for CS Thick, CHLS Res Mod, Road Type, SG Res Mod, SG PI, and SG Unit Wt can be assessed because they do not interact with any other factors. Plots for the statistically significant main effects and interaction effects are presented in Figures O-64 through O-80. The conclusions drawn based on those plots and the multiple comparison procedures are presented right after each plot. Multiple comparison procedures are used to determine if the differences in the average responses at different factor levels are statistically significant. For space, the tables containing the results of multiple comparison procedures are not presented here.

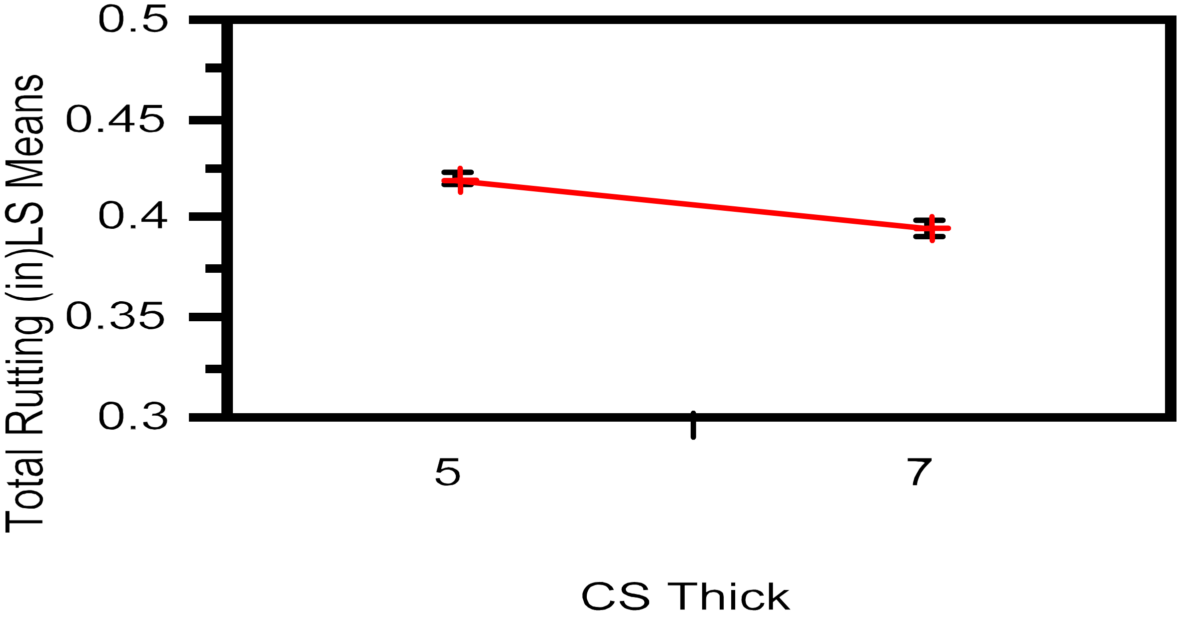

Figure O-64. Least Squares Means Plot for CS Thick (Total Rutting).

CS Thick 7 leads to less total rutting than CS Thick 5 does.

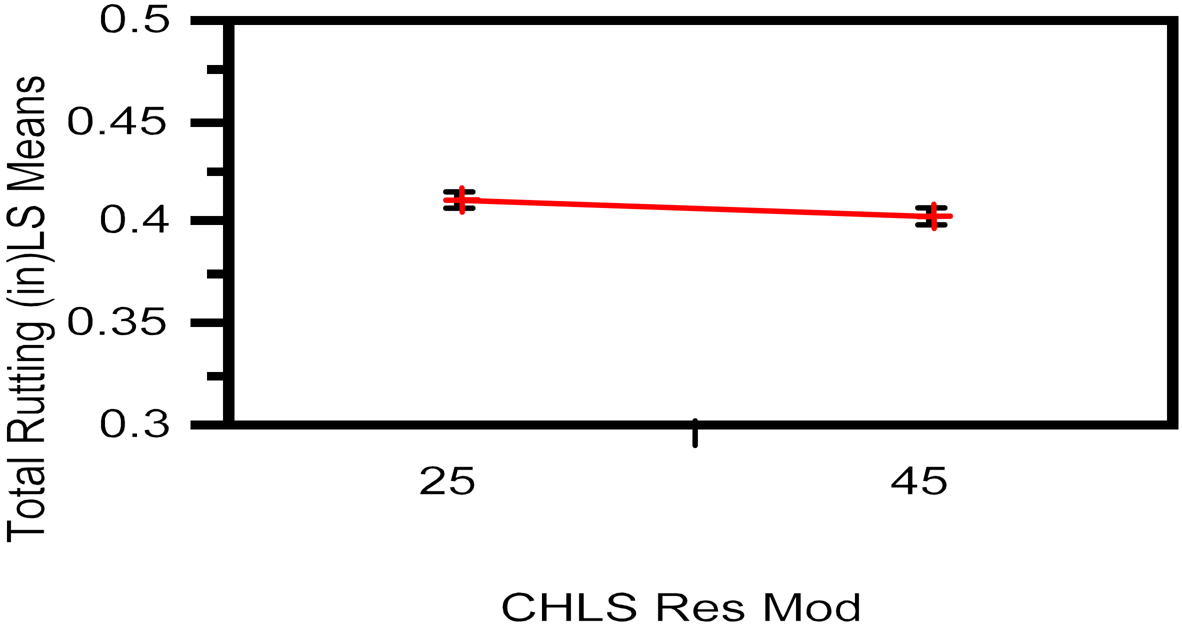

Figure O-65. Least Squares Means Plot for CHLS Res Mod (Total Rutting).

CHLS Res Mod 45 leads to less total rutting than CHLS Res Mod 25 does.

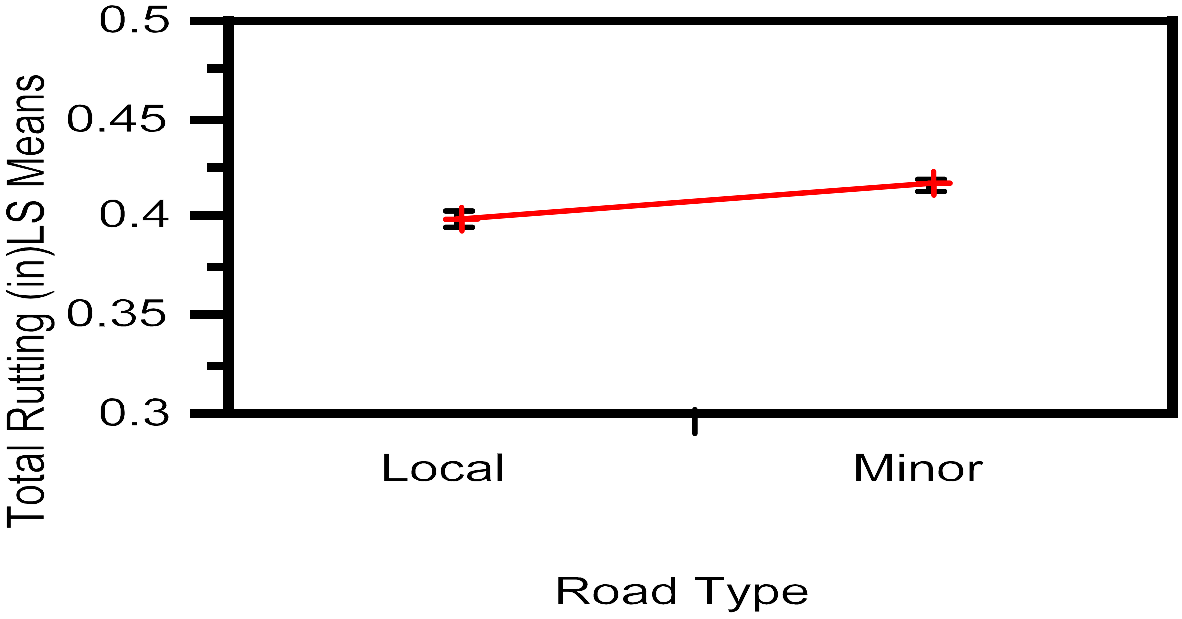

Figure O-66. Least Squares Means Plot for Road Type (Total Rutting).

Local Road leads to less total rutting than Minor Road does.

Figure O-67. Least Squares Means Plot for SG Res Mod (Total Rutting).

SG Res Mod 7k leads to less total rutting than SG Res Mod 17k does.

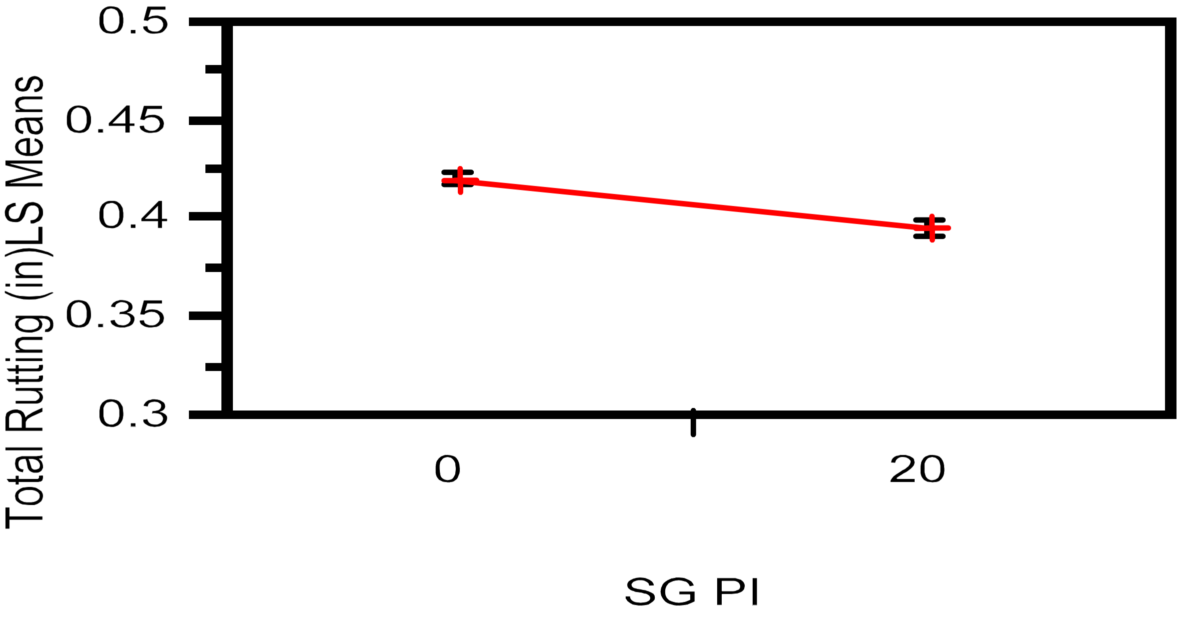

Figure O-68. Least Squares Means Plot for SG PI (Total Rutting).

SG PI 20 leads to less total rutting than SG PI 0 does.

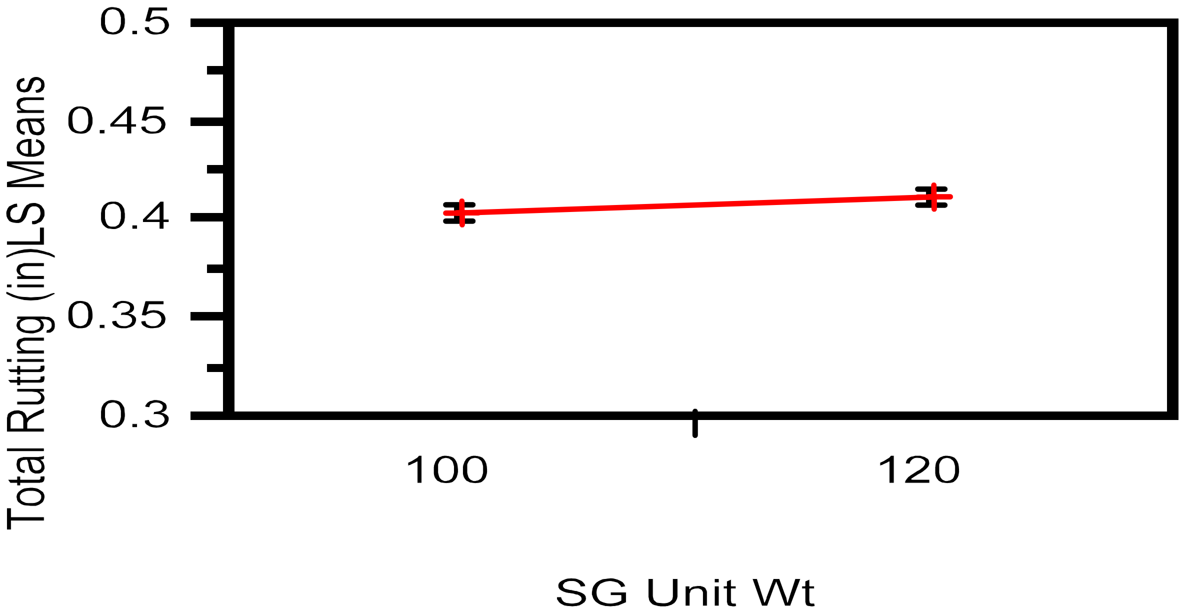

Figure O-69. Least Squares Means Plot for SG Unit Wt (Total Rutting).

SG Unit Wt 100 leads to less total rutting than SG Unit Wt 120 does.

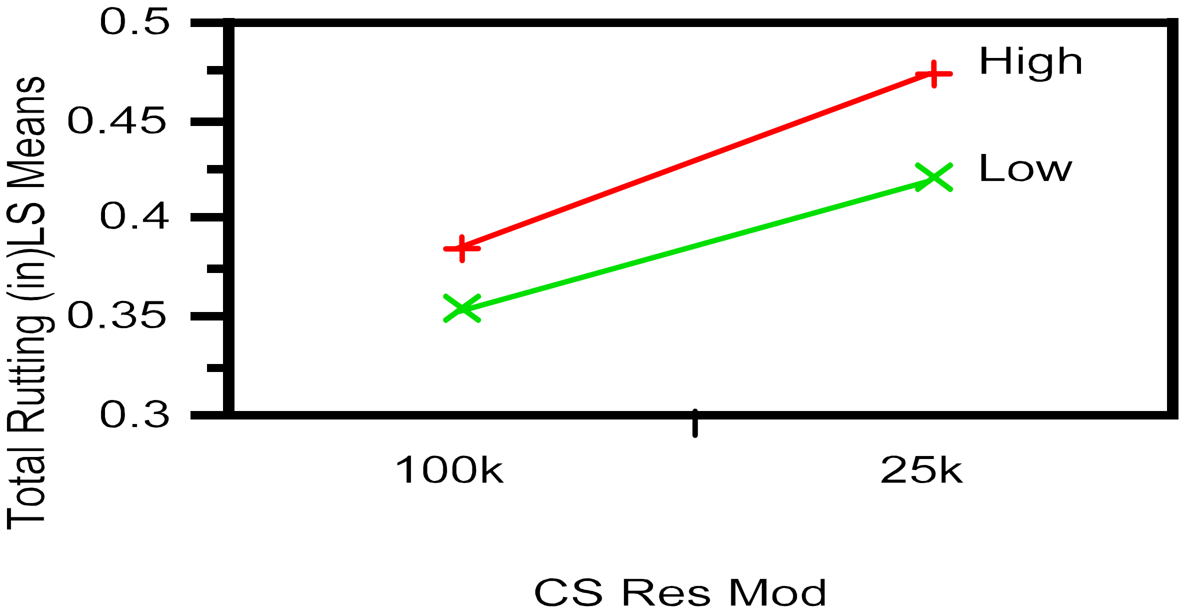

Figure O-70. Interaction Plot for CS Soil Water Value×CS Res Mod (Total Rutting).

In general, CS Soil Water Value High leads to more total rutting than CS Soil Water Value Low does, and CS Res Mod 25k leads to more Total AC rutting than CS Res Mod 100k does. The magnitude of increase is slightly different for each level of the other factor.

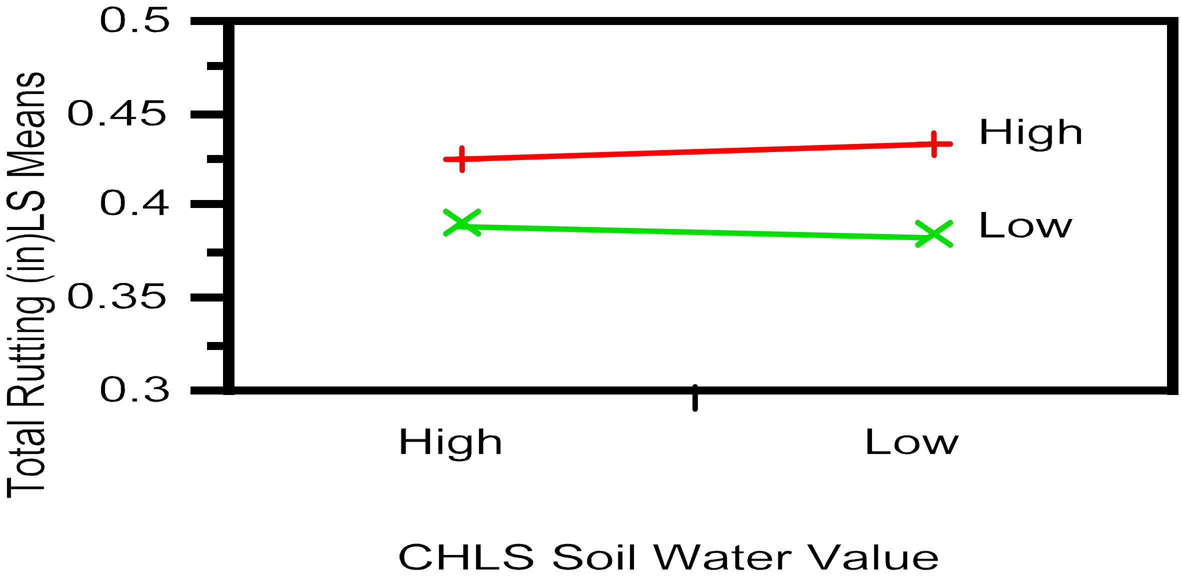

Figure O-71. Interaction Plot for CS Soil Water Value×CHLS Soil Water Value (Total Rutting).

In general, CS Soil Water Value High leads to more total rutting than CS Soil Water Value Low does. The effect of CS Soil Water Value is slightly stronger for CHLS Soil Water Value Low than High. There is no statistically significant effect of CHLS Soil Water Value on total rutting.

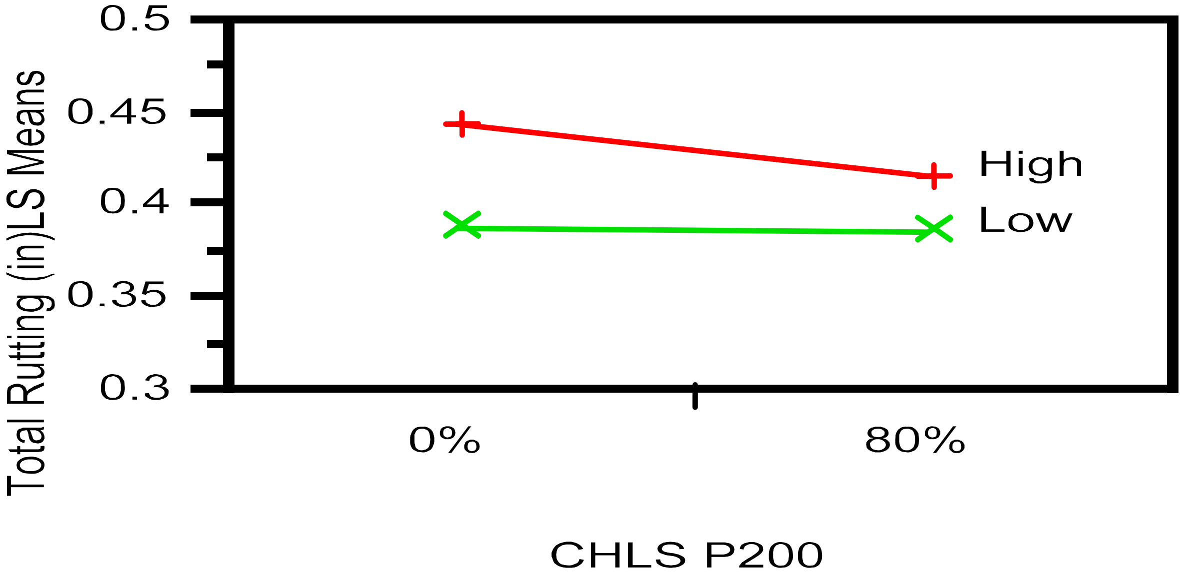

Figure O-72. Interaction Plot for CS Soil Water Value×CHLS P200 (Total Rutting).

CHLS P200 matters for CS Soil Water Value High but not for Low. In general, CS Soil Water Value High leads to more total rutting than CS Soil Water Value Low does.

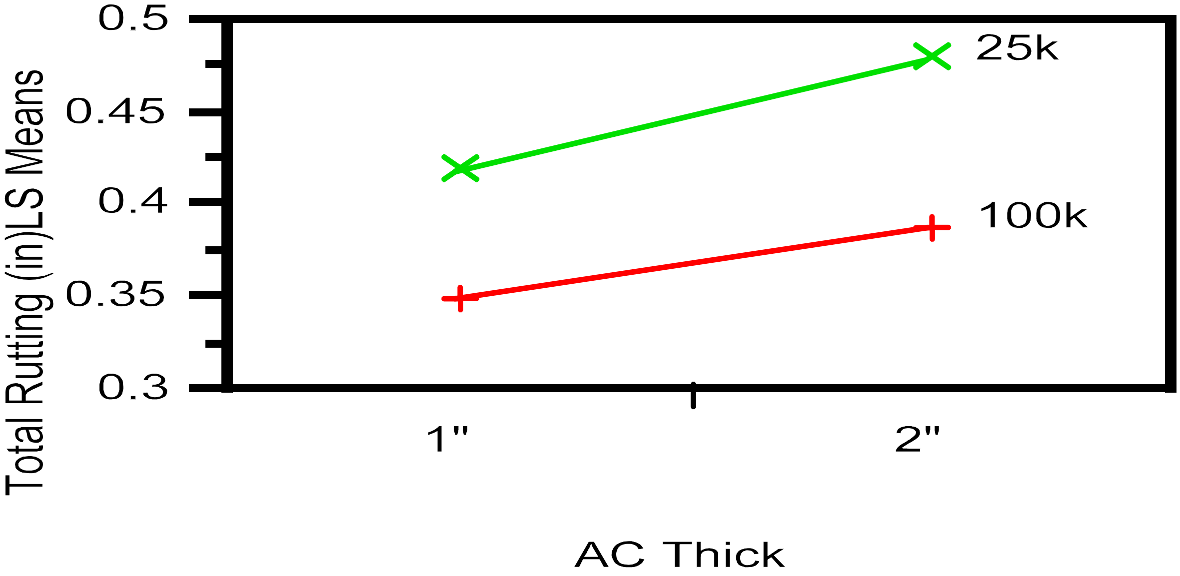

Figure O-73. Interaction Plot for CS Res Mod×AC Thick (Total Rutting).

In general, CS Res Mod 25k leads to more total rutting than CS Res Mod 100k does, and AC Thick 2" leads to more total rutting than AC Thick 1" does. The magnitude of increase is slightly different for each level of the other factor.

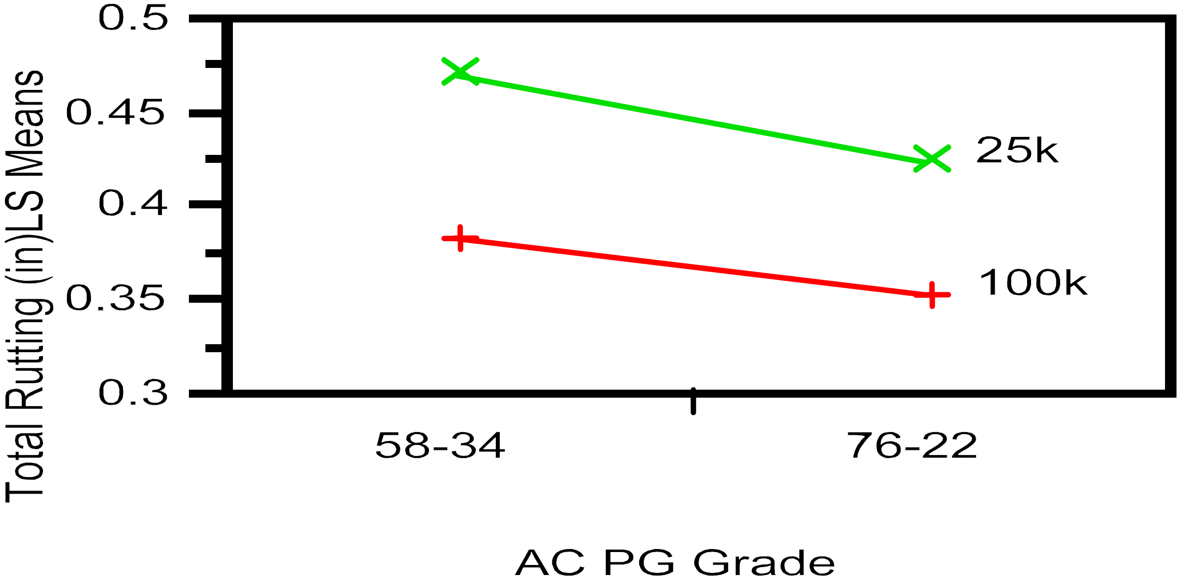

Figure O-74. Interaction Plot for CS Res Mod×AC PG Grade (Total Rutting).

In general, CS Res Mod 25k leads to more total rutting than CS Res Mod 100k does, and AC PG Grade 58-34 leads to more total rutting than AC PG Grade 76-22 does. The magnitude of increase is slightly different for each level of the other factor.

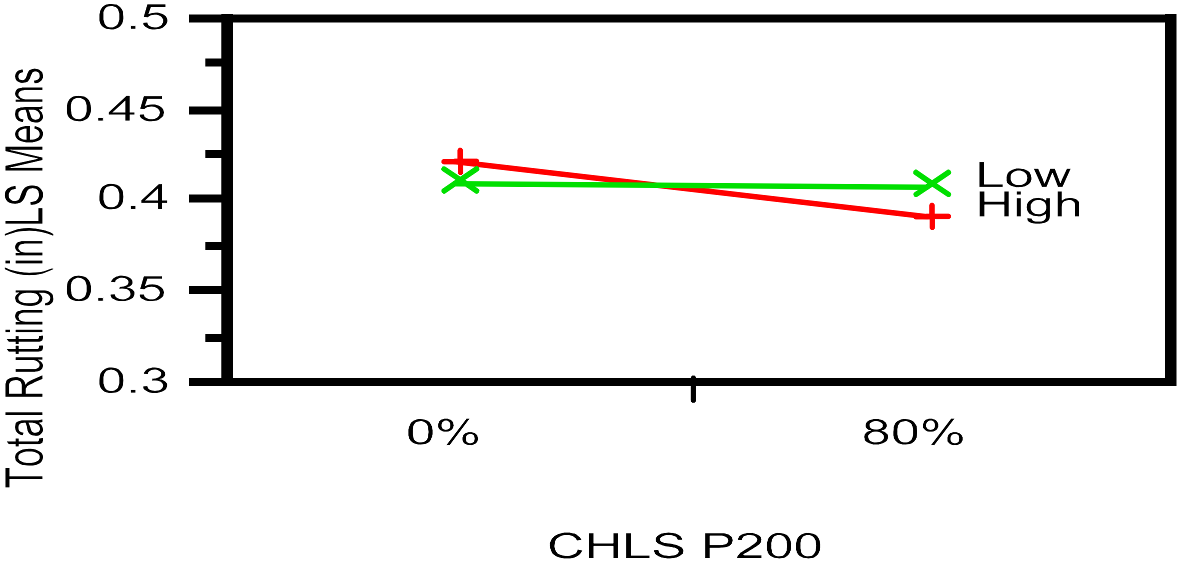

Figure O-75. Interaction Plot for CHLS Soil Water Value×CHLS P200 (Total Rutting).

CHLS P200 matters for high CHLS Soil Water Value, but not for low CHLS Soil Water Value (i.e., when CHLS Soil Water Value is High, CHLS P200 80% leads to less total rutting than CHLS P200 0% does). There is no statistically significant effect of CHLS P200 when CHLS Soil Water Value is Low.

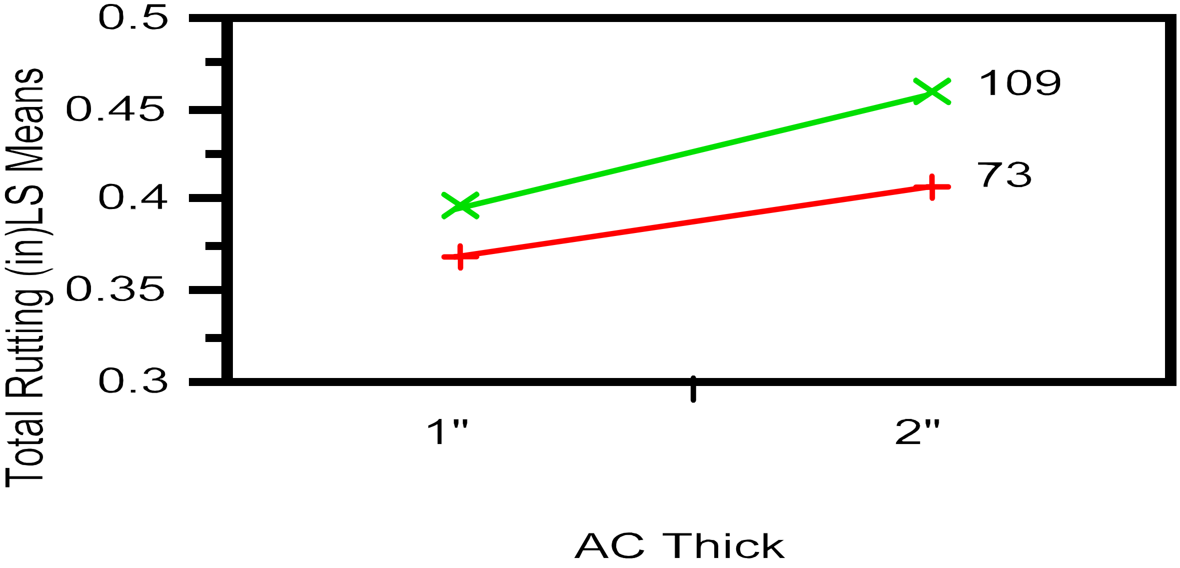

Figure O-76. Interaction Plot for AADT×AC Thick (Total Rutting).

In general, AC Thick 2" leads to more total rutting than AC Thick 1" does, and AADT 109 leads to more total rutting than AADT 73 does. The magnitude of increase is slightly different for each level of the other factor.

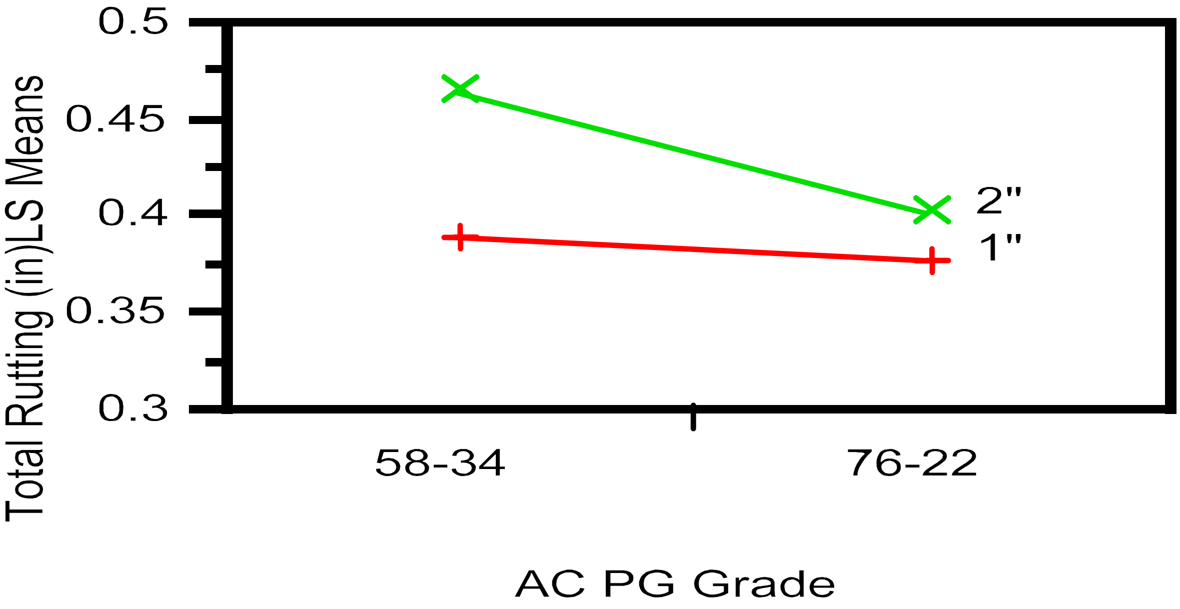

Figure O-77. Interaction Plot for AC Thick×AC PG Grade (Total Rutting).

In general, AC Thick 2" leads to more total rutting than AC Thick 1" does, and AC PG Grade 58-34 leads to more total rutting than AC PG Grade 76-22 does. The magnitude of increase is slightly different for each level of the other factor.

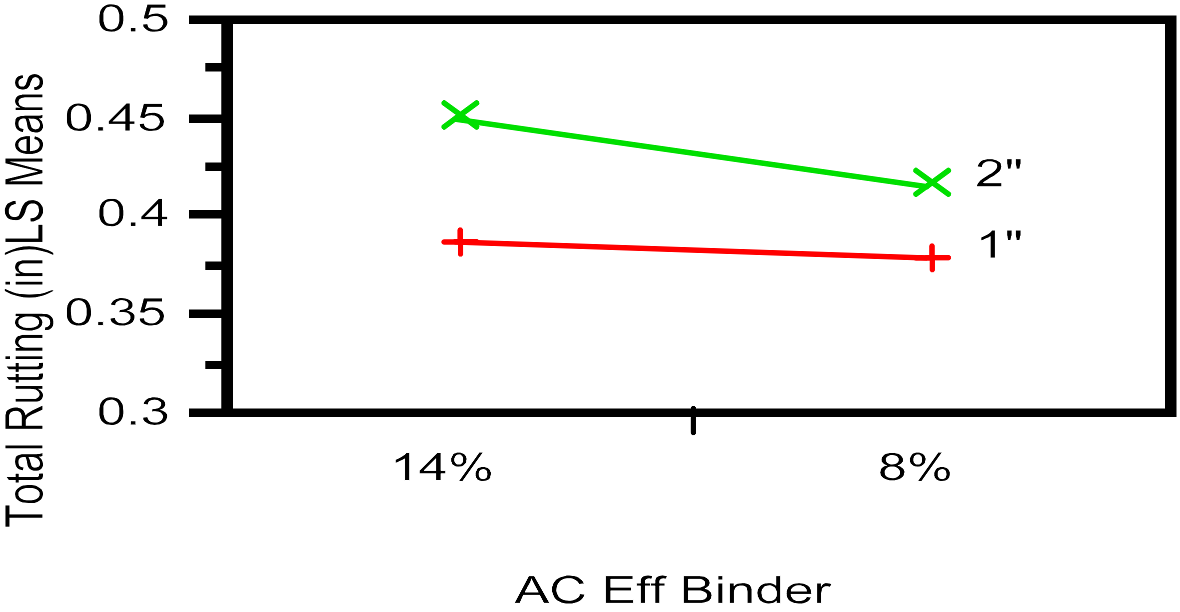

Figure O-78. Interaction Plot for AC Thick×AC Eff Binder (Total Rutting).

AC Thick 2" leads to more total rutting than AC Thick 1" regardless of the level of AC Eff Binder. AC Eff Binder matters for AC Thick 2", but not for AC Thick 1".

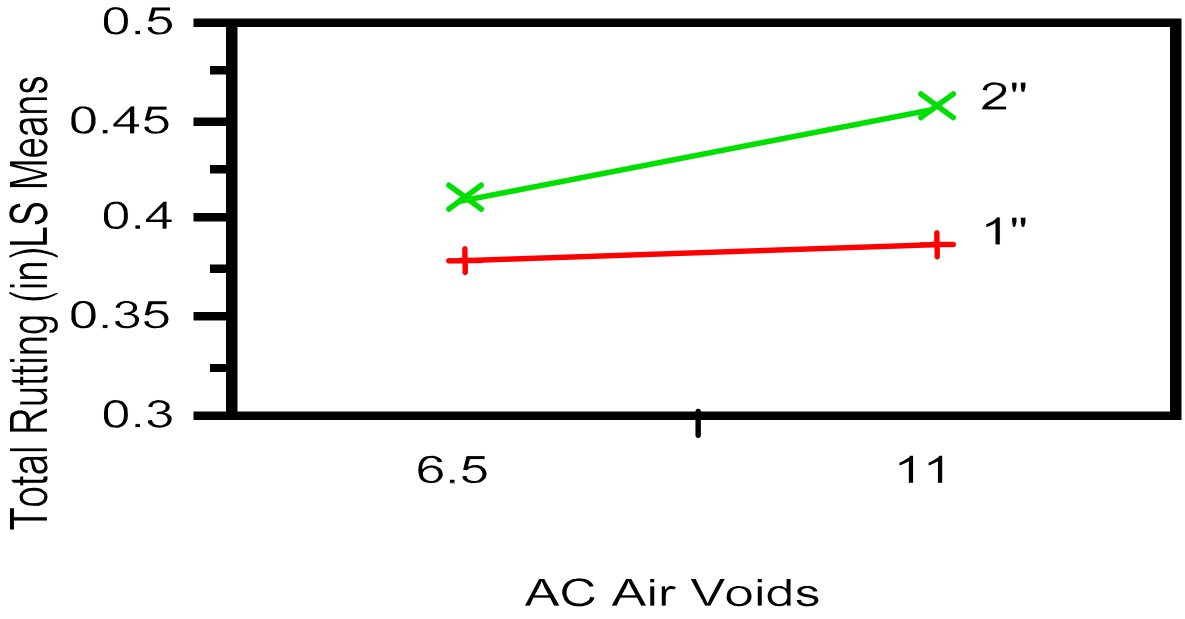

Figure O-79. Interaction Plot for AC Thick×AC Air Voids (Total Rutting).

AC Thick 2" leads to more total rutting than AC Thick 1" regardless of the level of AC Air Voids. AC Air Voids matters for AC Thick 2", but not for AC Thick 1".

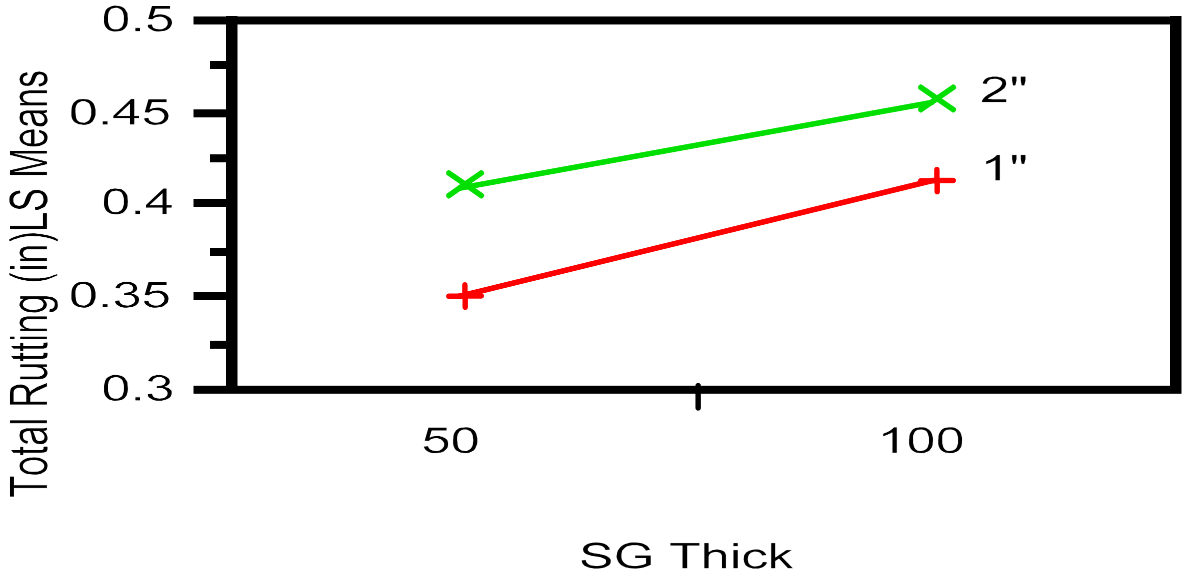

Figure O-80. Interaction Plot for AC Thick×SG Thick (Total Rutting).

In general, SG Thick 100 leads to more total rutting than SG Thick 50 does, and AC Thick 2" leads to more total rutting than AC Thick 1" does. The magnitude of increase is slightly different for each level of the other factor.

O.7 IRI

For IRI, a model in Table O-7 was selected as an adequate model with respect to the terms included by a stepwise variable selection procedure. All of the 18 interaction effects retained in the model are statistically significant at the level a=0.05. For the main effects, any terms included in the significant interaction effects are retained in the model. Note that the main effects CS Thick, CHLS Res Mod, AADT, AC PG Grade, SG Res Mod, and SG Unit Wt are not significant by themselves and they are not part of the significant interaction effects either, and so they were excluded from the final model.

Table O-7. Analysis of Variance for IRI.

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Model	30	337770017	11259001	16.42	<.0001
CS Soil Water Value	1	26537708	26537708	38.70	<.0001
CS Res Mod	1	58829662	58829662	85.79	<.0001
CHLS Soil Water Value	1	873	873	0.0013	0.9716
CHLS D60	1	3074597	3074597	4.48	0.0361
CHLS P200	1	5374461	5374461	7.84	0.0059
Const Date	1	1622422	1622422	2.37	0.1264
Road Type	1	86107	86107	0.13	0.7236
AC Thick	1	7739972	7739972	11.29	0.0010
AC Eff Binder	1	32525933	32525933	47.43	<.0001
AC Air Voids	1	20053922	20053922	29.24	<.0001
SG Thick	1	3601997	3601997	5.25	0.0235
SG PI	1	2737132	2737132	3.99	0.0478
CS Soil Water Value×CS Res Mod	1	15816835	15816835	23.06	<.0001
CS Soil Water Value×AC Thick	1	3784249	3784249	5.52	0.0203
CS Soil Water Value×AC Eff Binder	1	10923607	10923607	15.93	0.0001
CS Soil Water Value×AC Air Voids	1	9908346	9908346	14.45	0.0002
CS Res Mod×CHLS D60	1	3938733	3938733	5.74	0.0179
CS Res Mod×CHLS P200	1	7506814	7506814	10.95	0.0012
CS Res Mod×AC Thick	1	7355298	7355298	10.73	0.0013
CS Res Mod×AC Eff Binder	1	16111106	16111106	23.49	<.0001
CS Res Mod×AC Air Voids	1	25434943	25434943	37.09	<.0001
CS Res Mod×SG Thick	1	3554961	3554961	5.18	0.0244
CHLS Soil Water Value×CHLS D60	1	4725332	4725332	6.89	0.0097
CHLS Soil Water Value×CHLS P200	1	4936732	4936732	7.20	0.0082
CHLS D60×AC Air Voids	1	4090945	4090945	5.97	0.0159
CHLS P200×AC Air Voids	1	5458088	5458088	7.96	0.0055
Const Date×Road Type	1	9267895	9267895	13.51	0.0003
AC Thick×AC Eff Binder	1	3535869	3535869	5.16	0.0248
AC Eff Binder×AC Air Voids	1	13969184	13969184	20.37	<.0001
AC Air Voids×SG PI	1	3997452	3997452	5.83	0.0171
Error	133	91206635	685764		
C. Total	163	428976652			

For the factors that are involved in significant interaction effects, the individual factor effects can only be assessed conditional on each level of the other factor. Plots for the statistically significant interaction effects are presented in Figures O-81 through O-98. The conclusions drawn based on those plots and the multiple comparison procedures are presented right after each plot. Multiple comparison procedures are used to determine if the differences in the average responses at different factor levels are statistically significant. For space, the tables containing the results of multiple comparison procedures are not presented here.

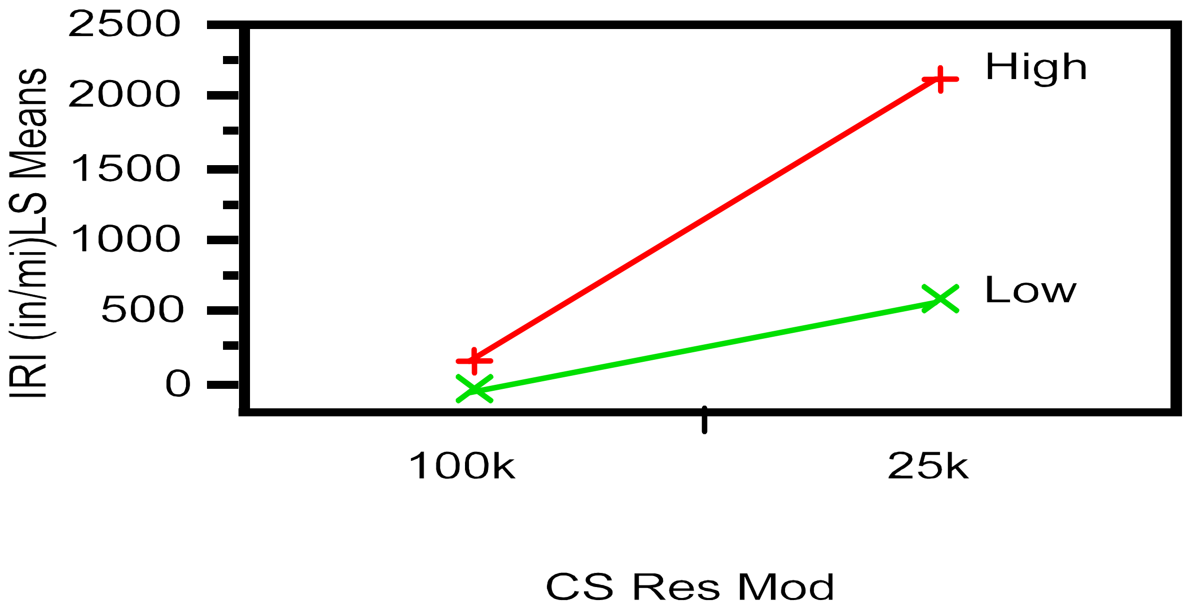

Figure O-81. Interaction Plot for CS Soil Water Value×CS Res Mod (IRI).

CS Res Mod 25k leads to more IRI than CS Res Mod 100k does regardless of the level of CS Soil Water Value. CS Soil Water Value matters (High CS Soil Water Value leads to more IRI than Low CS Soil Water Value) for CS Res Mod 25k, but not for CS Res Mod 100k.

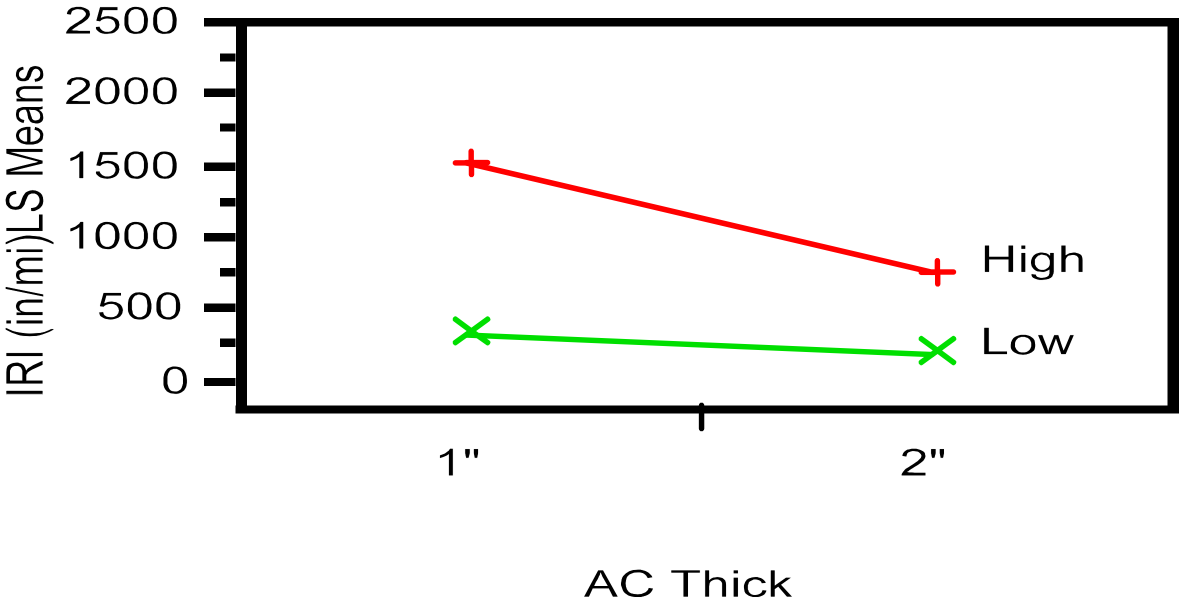

Figure O-82. Interaction Plot for CS Soil Water Value×AC Thick (IRI).

High CS Soil Water Value leads to more IRI than Low CS Soil Water Value does regardless of the level of AC Thick. AC Thick matters (AC Thick 1" leads to more IRI than AC Thick 2") for High CS Soil Water Value, but not for Low CS Soil Water Value.

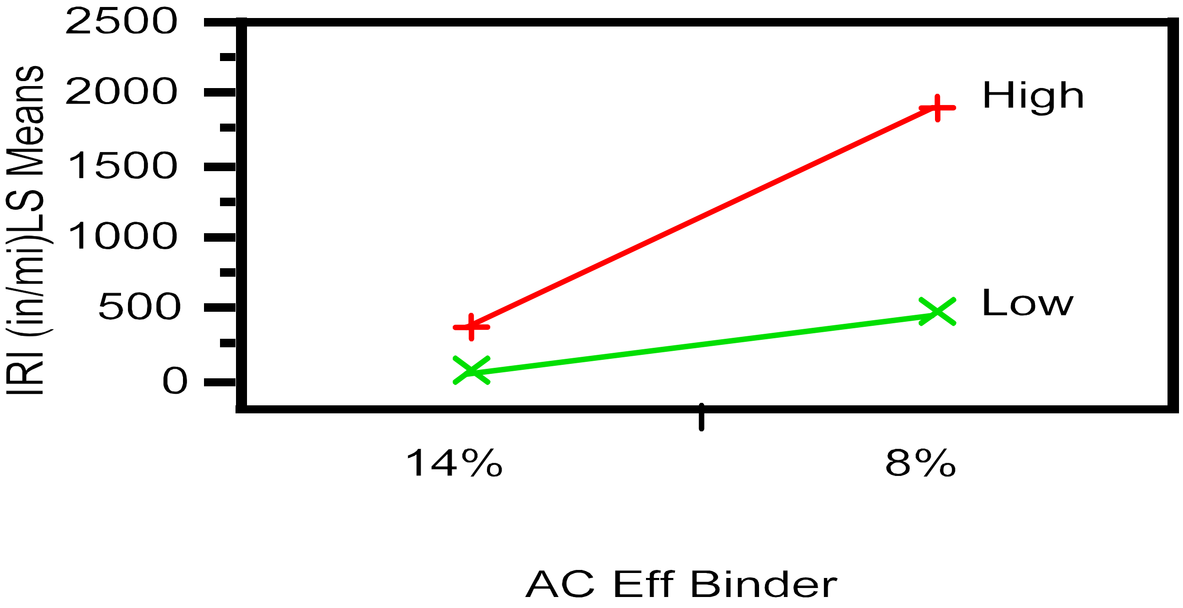

Figure O-83. Interaction Plot for CS Soil Water Value×AC Eff Binder (IRI).

AC Eff Binder matters (AC Eff Binder 8% leads to more IRI than AC Eff Binder 14%) for High CS Soil Water Value, but not for Low CS Soil Water Value. Said another way, CS Soil Water Value matters for AC Eff Binder 8%, but not for AC Eff Binder 14%.

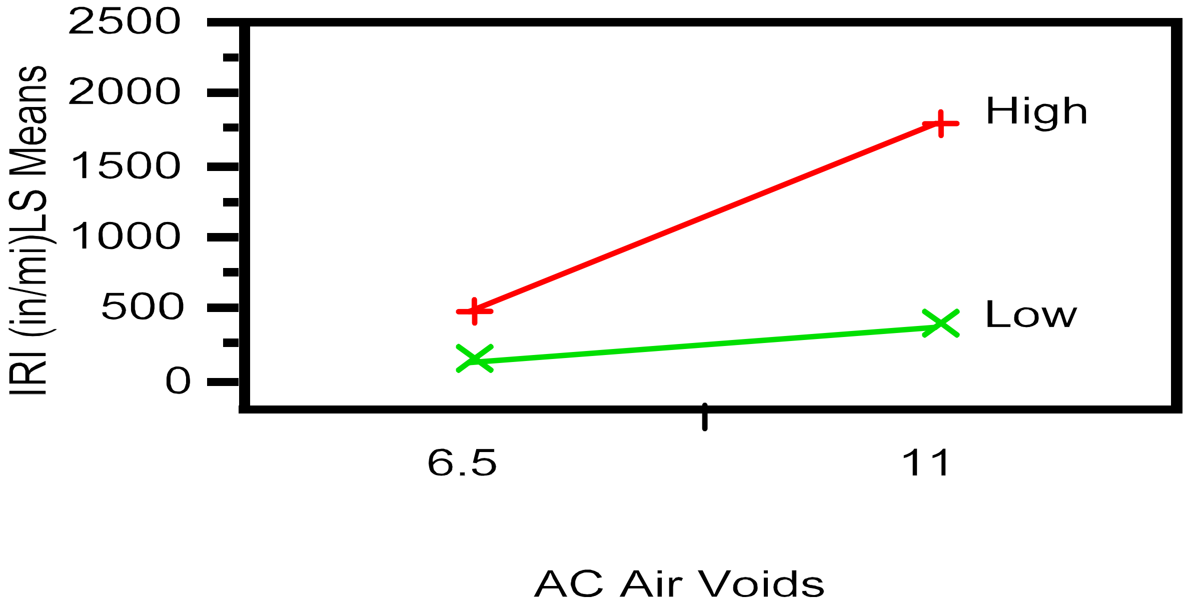

Figure O-84. Interaction Plot for CS Soil Water Value×AC Air Voids (IRI).

AC Air Voids matters (AC Air Voids 11 leads to more IRI than AC Air Voids 6.5) for High CS Soil Water Value, but not for Low CS Soil Water Value. Said another way, CS Soil Water Value matters for AC Air Voids 11, but not for AC Air Voids 6.5.

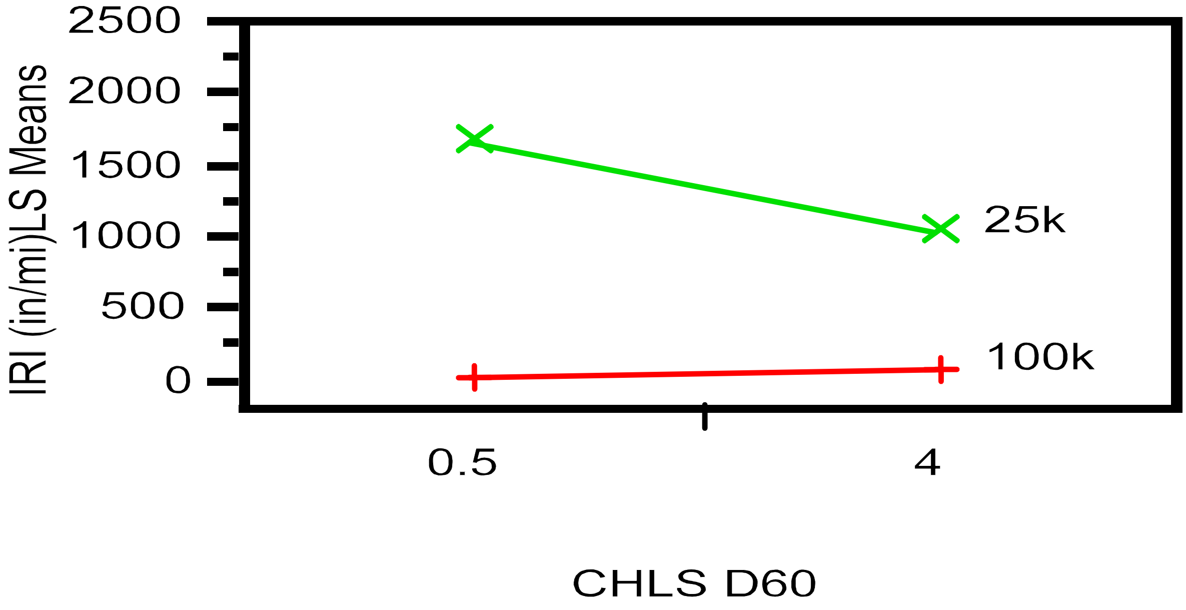

Figure O-85. Interaction Plot for CS Res Mod×CHLS D60 (IRI).

CS Res Mod 25k leads to more IRI than CS Res Mod 100k does regardless of the level of CHLS D60. CHLS D60 matters (CHLS D60 0.5 leads to more IRI than CHLS D60 4) for CS Res Mod 25k, but not for CS Res Mod 100k.

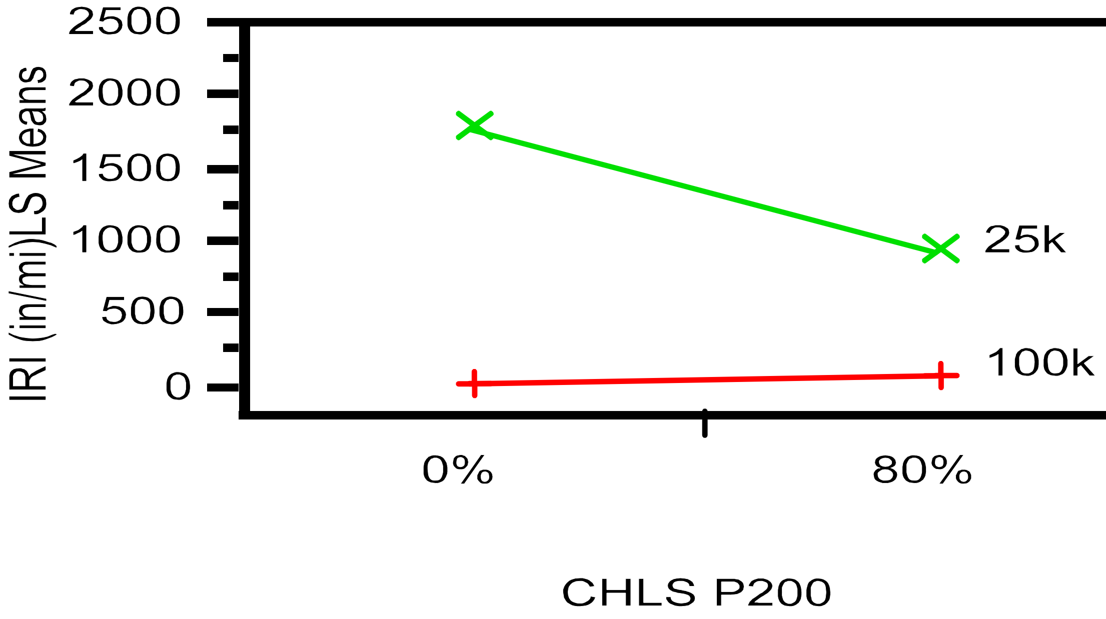

Figure O-86. Interaction Plot for CS Res Mod×CHLS P200 (IRI).

CS Res Mod 25k leads to more IRI than CS Res Mod 100k does regardless of the level of CHLS P200. CHLS P200 matters (CHLS P200 0% leads to more IRI than CHLS P200 80%) for CS Res Mod 25k, but not for CS Res Mod 100k.

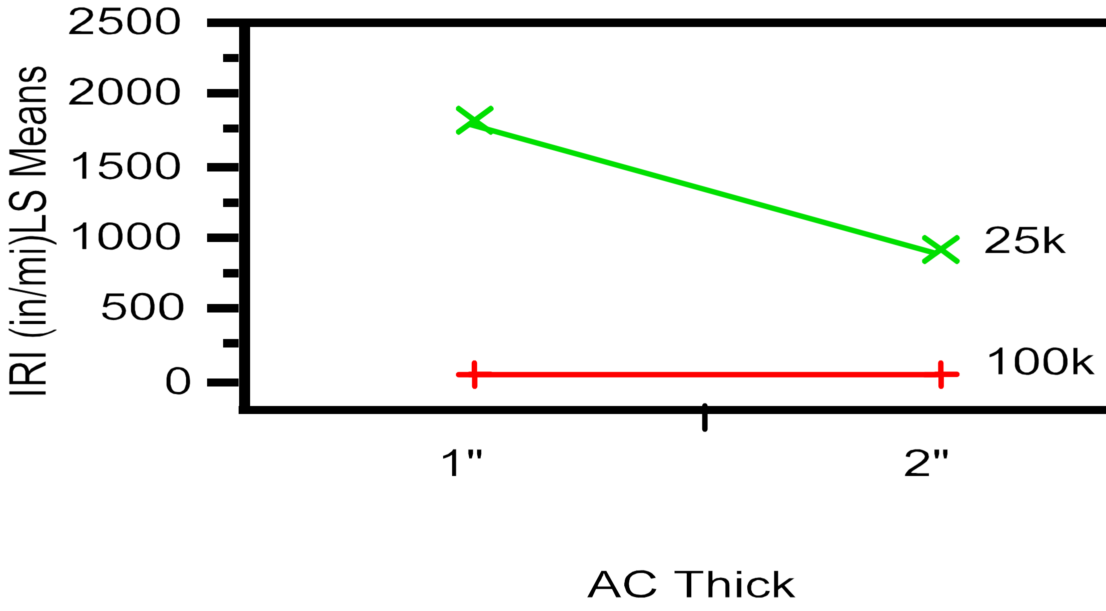

Figure O-87. Interaction Plot for CS Res Mod×AC Thick (IRI).

CS Res Mod 25k leads to more IRI than CS Res Mod 100k does whether AC Thick is 1" or 2". AC Thick matters (AC Thick 1" leads to more IRI than AC Thick 2") for CS Res Mod 25k, but not for CS Res Mod 100k.

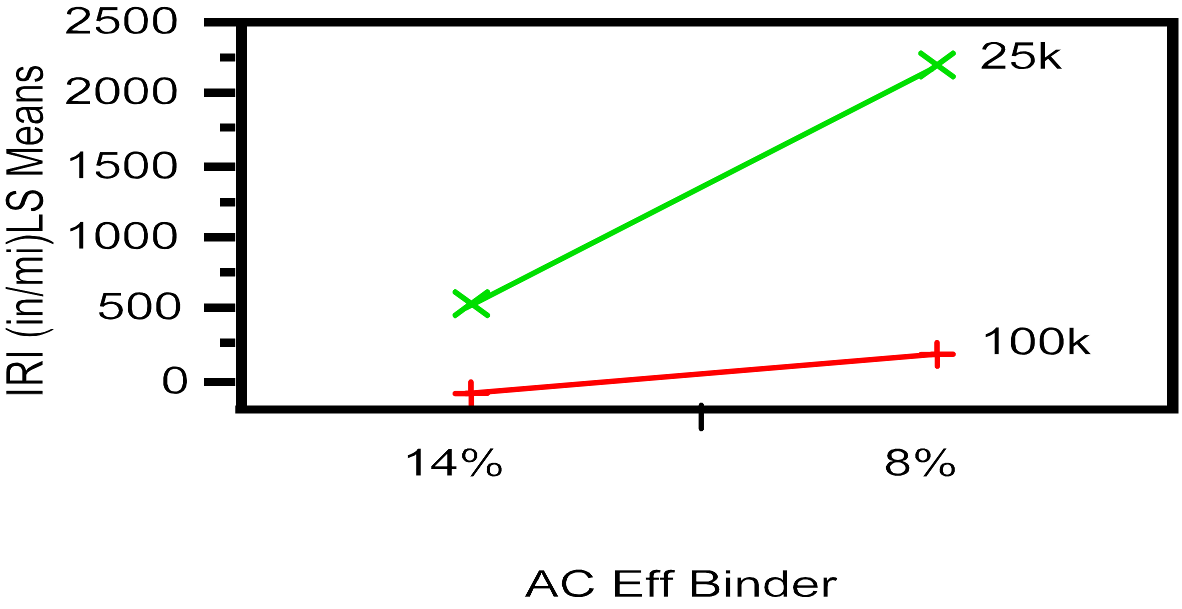

Figure O-88. Interaction Plot for CS Res Mod×AC Eff Binder (IRI).

CS Res Mod 25k leads to more IRI than CS Res Mod 100k does whether AC Eff Binder is 8% or 14%. AC Eff Binder matters (AC Eff Binder 8% leads to more IRI than AC Eff Binder 14%) for CS Res Mod 25k, but not for CS Res Mod 100k.

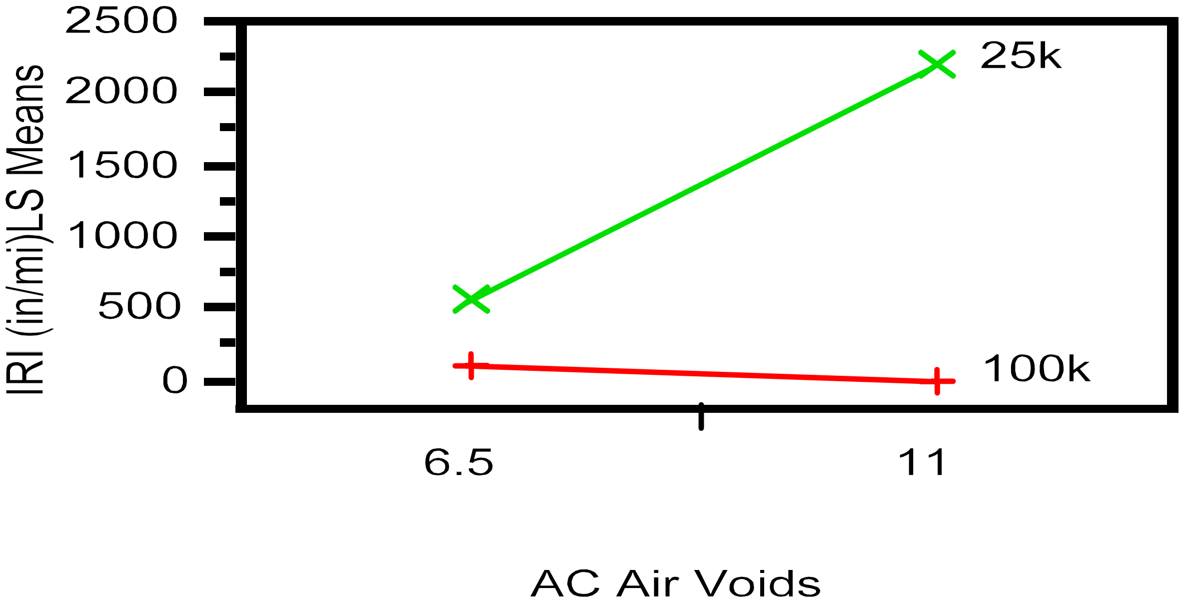

Figure O-89. Interaction Plot for CS Res Mod×AC Air Voids (IRI).

AC Air Voids matters (AC Air Voids 11 leads to more IRI than AC Air Voids 6.5) for CS Res Mod 25k, but not for CS Res Mod 100k. Said another way, CS Res Mod matters (CS Res Mod 25k leads to more IRI than CS Res Mod 100k) for AC Air Voids 11, but not for AC Air Voids 6.5.

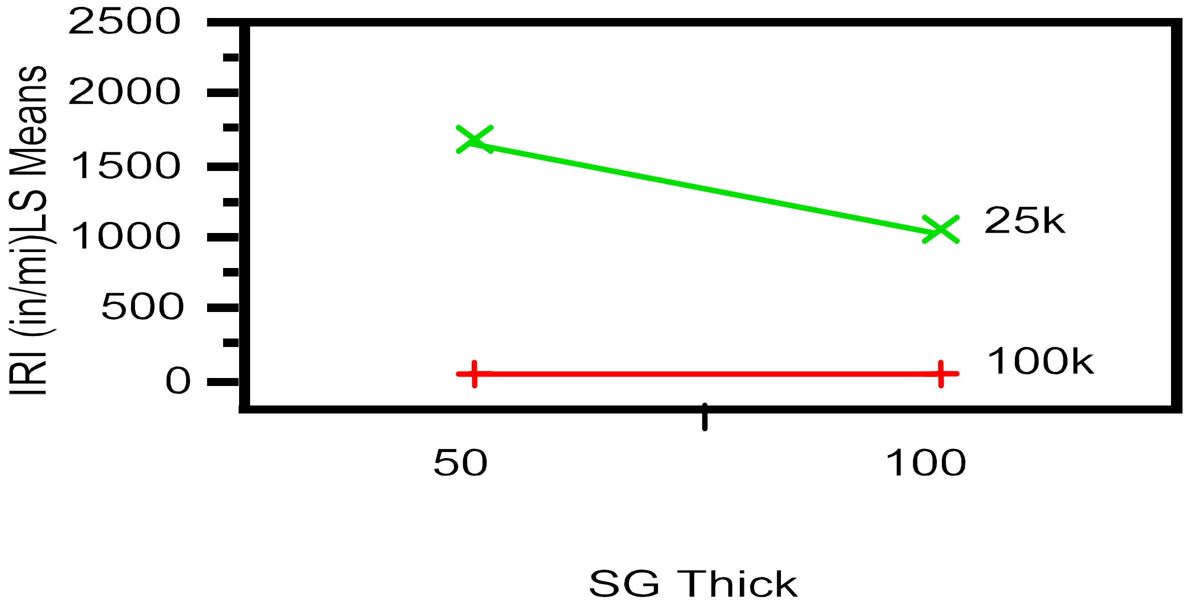

Figure O-90. Interaction Plot for CS Res Mod×SG Thick (IRI).

CS Res Mod 25k leads to more IRI than CS Res Mod 100k does whether SG Thick is 50 or 100. SG Thick matters (SG Thick 50 leads to more IRI than SG Thick 100) for CS Res Mod 25k, but not for CS Res Mod 100k.

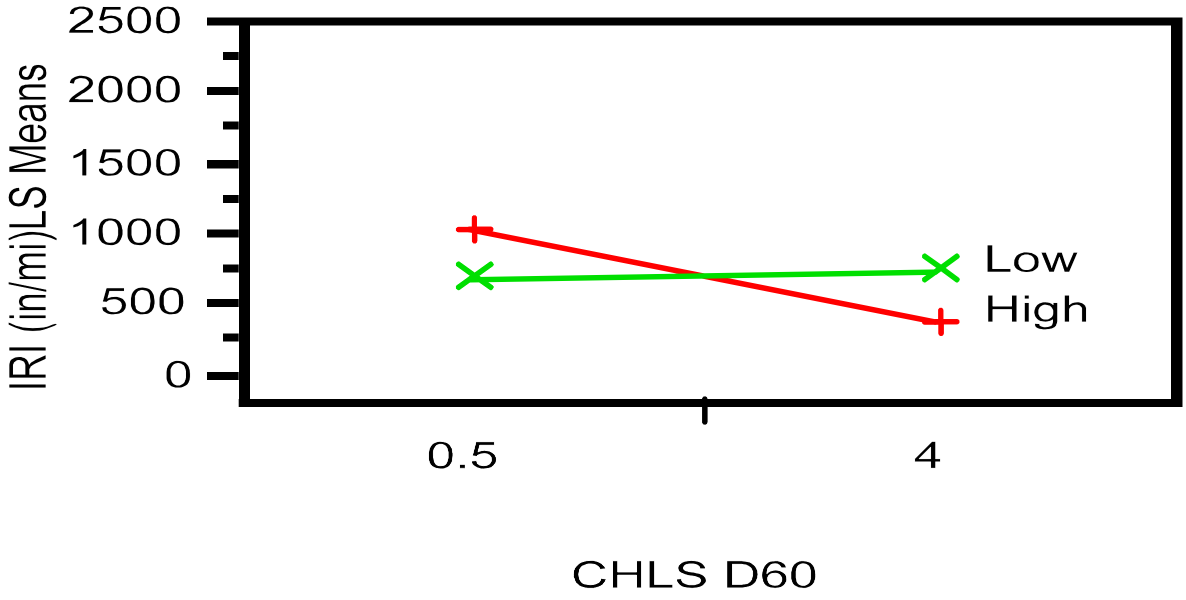

Figure O-91. Interaction Plot for CHLS Soil Water Value×CHLS D60 (IRI).

CHLS D60 matters (CHLS D60 0.5 leads to more IRI than CHLS D60 4) for High CHLS Soil Water Value, but not for Low CHLS Soil Water Value. CHLS Soil Water Value does not matter (mean IRIs for Low CHLS Soil Water Value and for High CHLS Soil Water Value are not statistically different) whether CHLS D60 is 0.5 or 4.

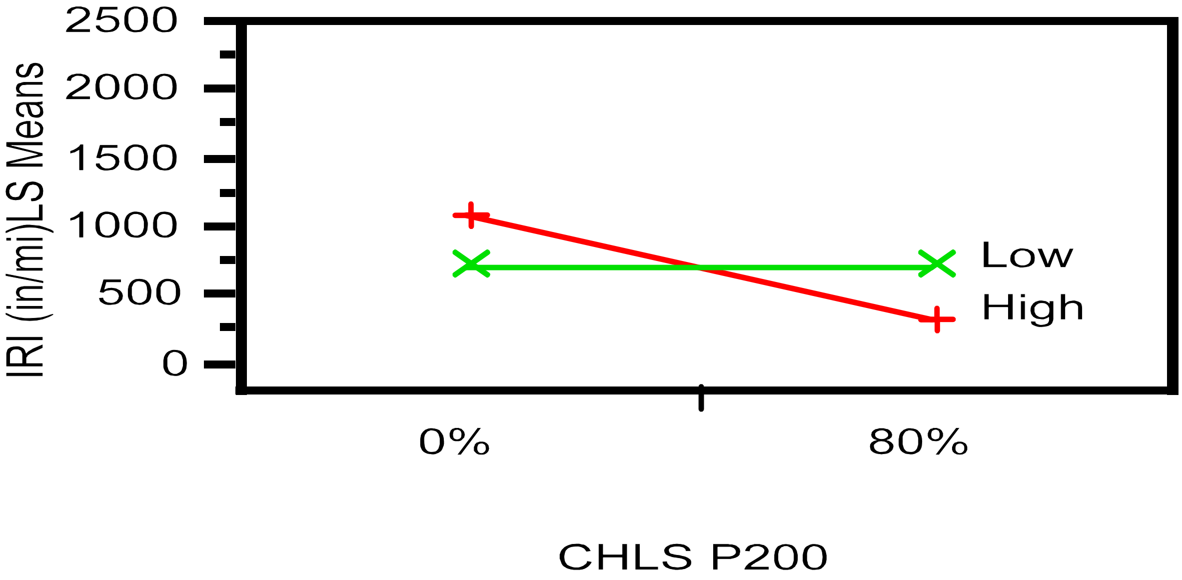

Figure O-92. Interaction Plot for CHLS Soil Water Value×CHLS P200 (IRI).

CHLS P200 matters (CHLS P200 0% leads to more IRI than CHLS P200 80%) for High CHLS Soil Water Value, but not for Low CHLS Soil Water Value. CHLS Soil Water Value does not matter (mean IRIs for Low CHLS Soil Water Value and for High CHLS Soil Water Value are not statistically different) whether CHLS P200 is 0% or 80%.

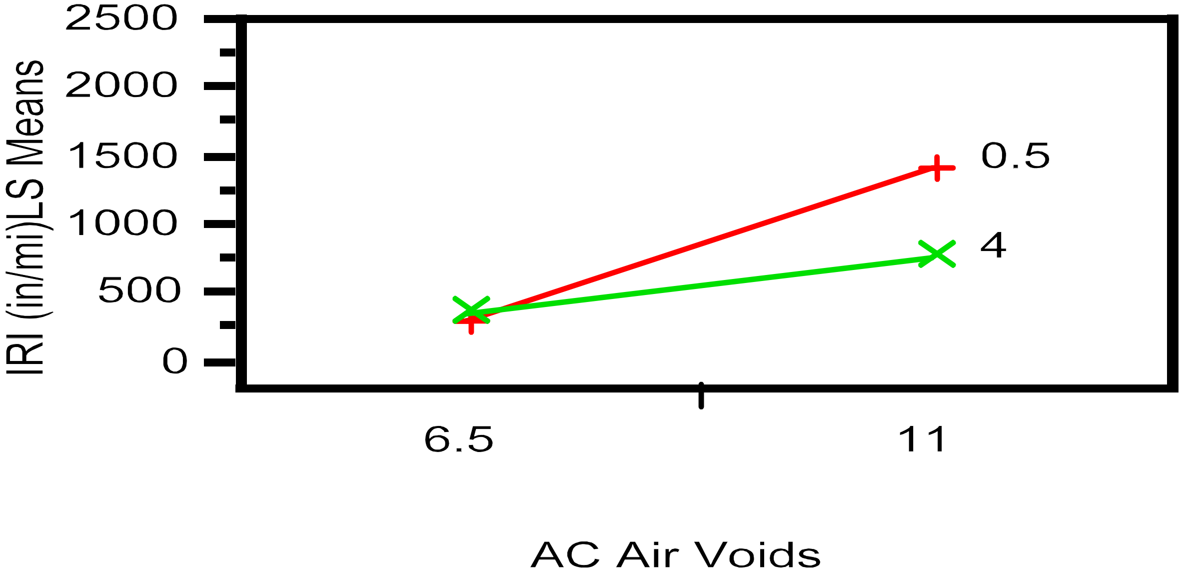

Figure O-93. Interaction Plot for CHLS D60×AC Air Voids (IRI).

CHLS D60 matters (CHLS D60 0.5 leads to more IRI than CHLS D60 4) for AC Air Voids 11, but not for AC Air Voids 6.5. Said another way, AC Air Voids matters (11 leads to more IRI than 6.5 does) for CHLS D60 0.5, but not for CHLS D60 4.

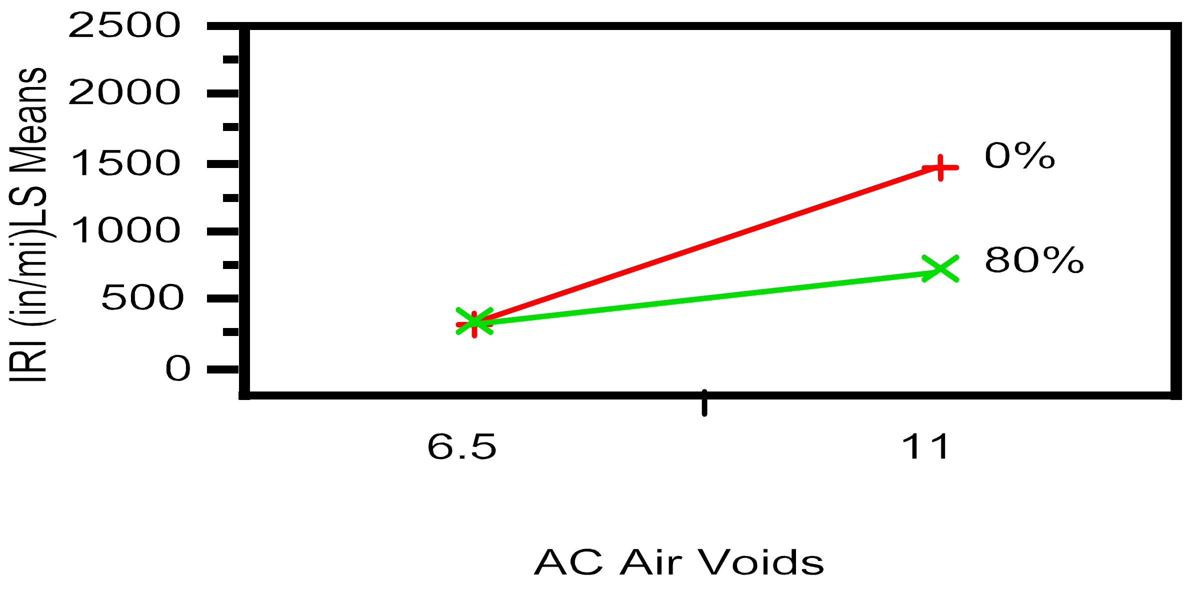

Figure O-94. Interaction Plot for CHLS P200×AC Air Voids (IRI).

CHLS P200 matters (CHLS P200 0% leads to more IRI than CHLS P200 80%) for AC Air Voids 11, but not for AC Air Voids 6.5. Said another way, AC Air Voids matters (11 leads to more IRI than 6.5 does) for CHLS P200 0%, but not for CHLS P200 80%.

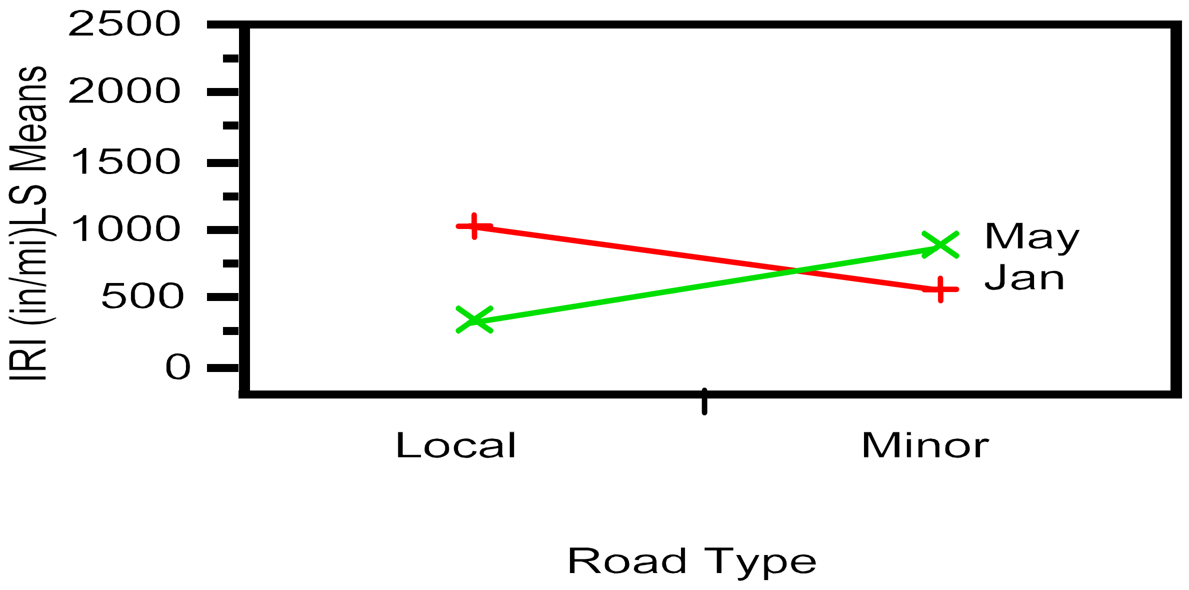

Figure O-95. Interaction Plot for Const Date×Road Type (IRI).

Road Type matters (Minor Road leads to more IRI than Local Road) for May, but not for January. Said another way, Const Date matters (January leads to more IRI than May does) for Local Road, but not for Minor Road.

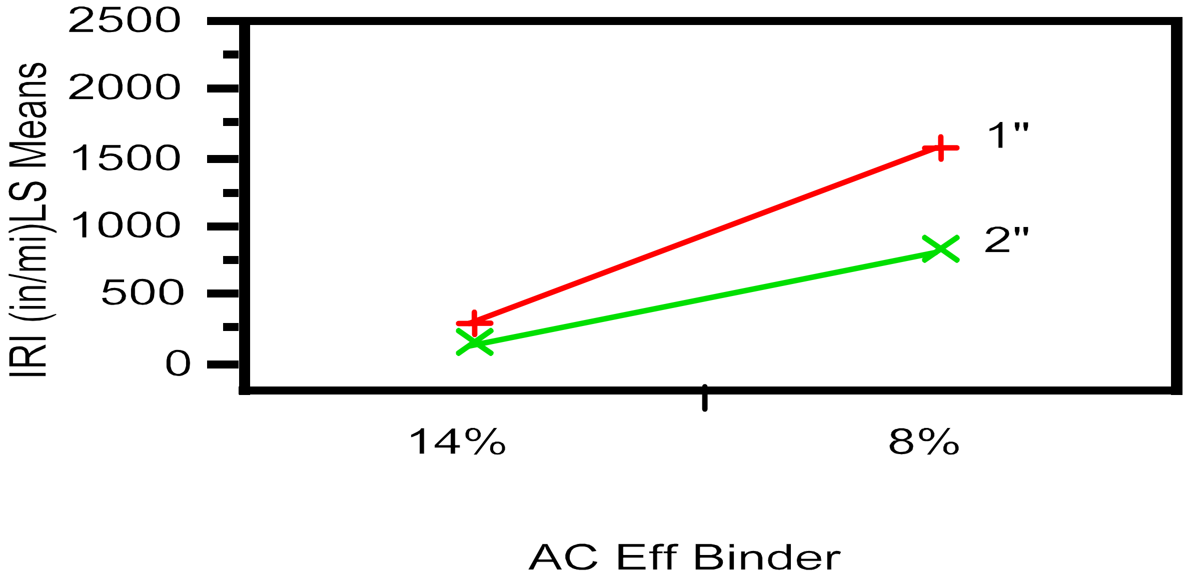

Figure O-96. Interaction Plot for AC Thick×AC Eff Binder (IRI).

AC Thick matters (1" leads to more IRI than 2" does) for AC Eff Binder 8%, but not for AC Eff Binder 14%. AC Eff Binder 8% leads to more IRI than AC Eff Binder 14% does whether AC Thick is 1" or 2".

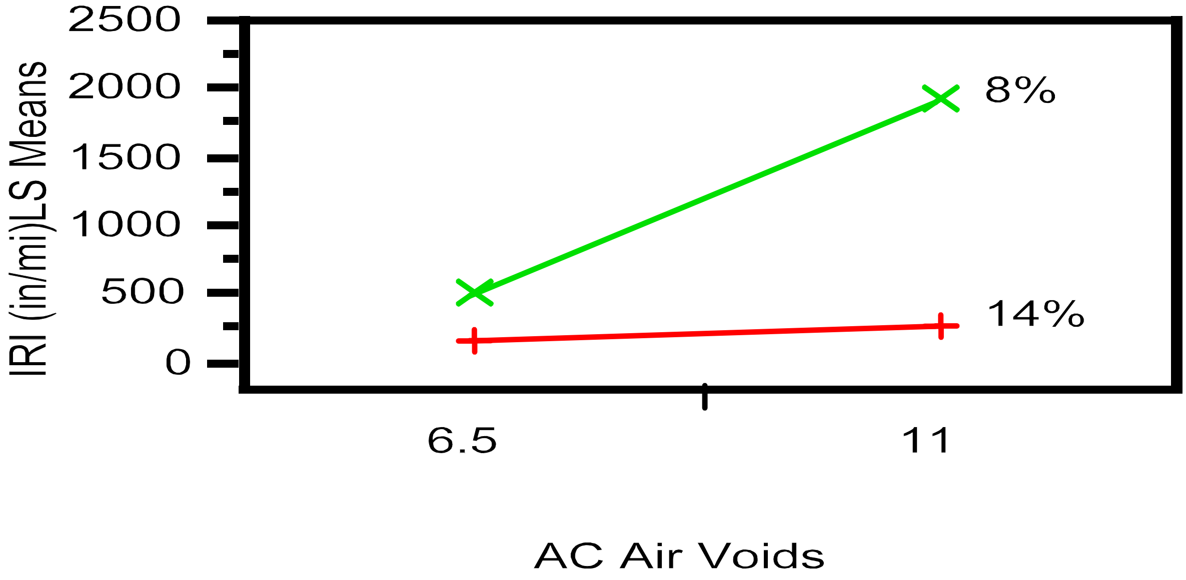

Figure O-97. Interaction Plot for AC Eff Binder×AC Air Voids. (IRI).

AC Air Voids matters (11 leads to more IRI than 6.5 does) for AC Eff Binder 8%, but not for AC Eff Binder 14%. Said another way, AC Eff Binder matters for AC Air Voids 11 (8% leads to more IRI than AC Eff Binder 14% does), but not for AC Air Voids 6.5.

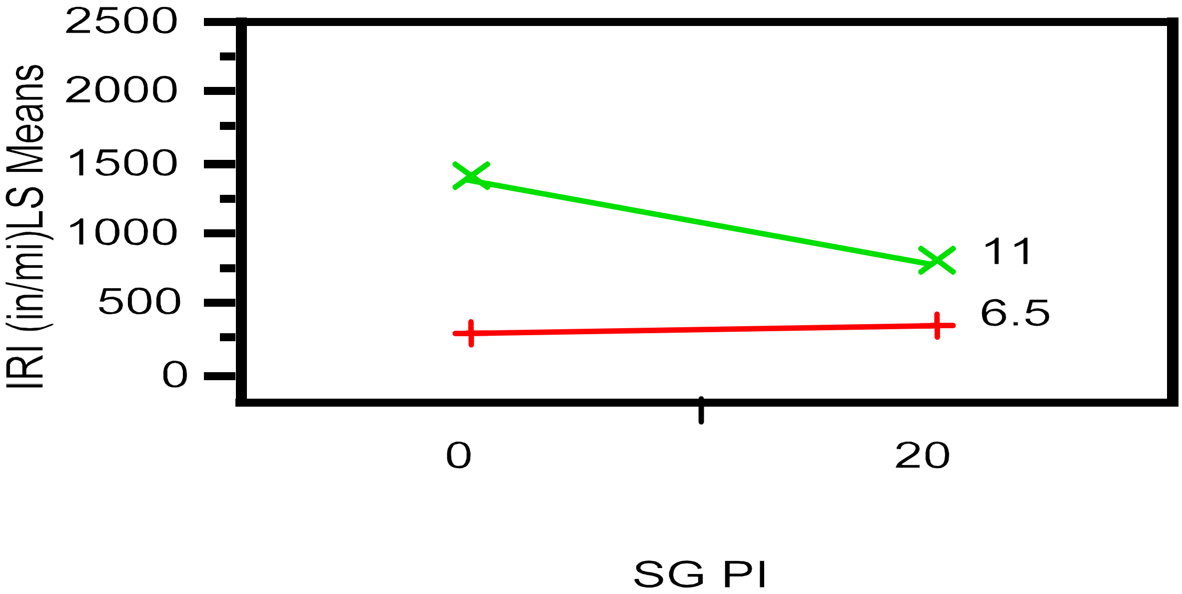

Figure O-98. Interaction Plot for AC Air Voids×SG PI (IRI).

AC Air Voids matters (11 leads to more IRI than 6.5 does) when SG PI is 0, but not when SG PI is 20. Said another way, SG PI matters for AC Air Voids 11 (0 leads to more IRI than 20 does), but not for AC Air Voids 6.5.

REFERENCES

Sanford Weisberg, *Applied Linear Regression*, 1985, New York: John Wiley & Sons.

APPENDIX P

MULTIPLE VARIABLE ANALYSIS FOR CONTINUOUSLY REINFORCED CONCRETE PAVEMENTS

MULTIPLE VARIABLE ANALYSIS - CONTINUOUSLY REINFORCED CONCRETE PAVEMENTS

P.1 CRCP PUNCHOUT ANALYSIS

The punchout data for CRCP pavements from the M-E Design Guide for various factor-level combinations for each of the Dry-Cold and the Wet-Warm region were analyzed to identify the important factors that affect punchouts. Tables P-1 and P-2 contain the factors and their corresponding levels investigated.

Table P-1. Factors for the Dry-Cold Region.

Factors	Levels							
CRC Thickness	11				15			
Coefficient of Contraction	4				9			
Zero Stress Temp	90				130			
Strength	E-5000	E-3200	Level 1 High	Level 1 Low	Level 2 High	Level 2 Low	Mr = 670	Mr = 580
AADT	6400				9600			
Curl/Warp Temp Diff	-15				-6			
Steel %	0.4				0.8			
Steel Cover	at ¼ depth				Default			
Base/Slab Friction Coeff	10				3.7			

Table P-2. Factors for the Wet-Warm Region.

Factors	Levels							
CRC Thickness	11				15			
Coefficient of Contraction	4				9			
Zero Stress Temp	90				130			
Strength	E-5000	E-3200	Level 1 High	Level 1 Low	Level 2 High	Level 2 Low	Mr = 670	Mr = 580
AADT	6400				9600			
Curl/Warp Temp Diff	-15				-6			
Steel %	0.4				0.8			
Base/Slab Friction Coeff	10				3.7			

Analysis of Variance (ANOVA) was employed to analyze the data. For the Dry-Cold region, models with CRC Thickness, Coefficient of Contraction, Zero Stress Temperature, Strength, AADT, Curl/Warp Temperature Difference, Steel %, Steel Cover, and Base/Slab Friction Coefficient as main effects and all possible two-way interactions were explored. There were originally 36 possible two-way interactions in addition to the 9 main effects. Table P-3 contains the analysis of variance table for the model in Table P-4, which shows the model is significant at α = 0.05. Based on the backward elimination procedure removing the insignificant interactions from the model one by one, a model in Table P-4 was selected as an adequate model with respect to the terms included. All of the 22 interaction effects retained in the model were statistically significant at the level α = 0.05.

Table P-3. Analysis of Variance.

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	85	10800.56	127.06	70.31
Error	14	25.30	1.81	**Prob > F**
C. Total	99	10825.86		<.0001

Table P-4. Effect Tests.

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
CRC Thickness	1	1	273.88	151.54	<.0001
Coeff of Contract	1	1	296.26	163.93	<.0001
Zero Stress Temp	1	1	0.418	0.23	0.6382
Strength	7	7	209.34	16.55	<.0001
AADT	1	1	9.73	5.39	0.0359
Curl_Warp	1	1	81.68	45.20	<.0001
Steel Percent	1	1	355.06	196.46	<.0001
Steel Cover	1	1	3.25	1.80	0.2014
Base/Slab Friction	1	1	64.59	35.74	<.0001
CRC Thickness×Coeff of Contrct	1	1	73.78	40.82	<.0001
Coeff of Contrct×Zero Stress Temp	1	1	11.04	6.11	0.0269
CRC Thickness×Strength	7	7	64.12	5.07	0.0048
Coeff of Contrct×Strength	7	7	130.83	10.34	0.0001
Zero Stress Temp×Strength	7	7	86.94	6.87	0.0012
Coeff of Contrct×AADT	1	1	12.56	6.95	0.0195
Strength×AADT	7	7	114.08	9.02	0.0003
CRC Thickness×Curl_Warp	1	1	58.62	32.44	<.0001
Strength×Curl_Warp	7	7	90.47	7.15	0.0009
AADT×Curl_Warp	1	1	20.26	11.21	0.0048
CRC Thickness×Steel Percent	1	1	21.75	12.03	0.0038
Coeff of Contrct×Steel Percent	1	1	11.13	6.16	0.0264
Strength×Steel Percent	7	7	100.51	7.95	0.0006
Curl_Warp×Steel Percent	1	1	17.19	9.51	0.0081
CRC Thickness×Steel Cover	1	1	10.30	5.70	0.0316
Strength×Steel Cover	7	7	79.85	6.31	0.0018
AADT×Steel Cover	1	1	49.04	27.14	0.0001
Curl_Warp×Steel Cover	1	1	12.99	7.19	0.0179
Steel Percent×Steel Cover	1	1	16.09	8.90	0.0099
Coeff of Contrct×Base/Slab Fric	1	1	18.52	10.25	0.0064
Zero Stress Temp×Base/Slab Fric	1	1	19.57	10.83	0.0054
Strength×Base/Slab Fric	7	7	130.30	10.30	0.0001

Since there are significant interaction effects (joint effects of two factors), the individual factor effects (main effects) can only be assessed conditional on each level of the other factor. Plots for the statistically significant interaction effects are presented in Figures P-1 through P-22. Interaction plots are often helpful for interpretation of interaction effects. In an interaction plot, the y axis is the average response. An interaction plot shows the effect of two factors on the response. One factor is on the x axis. This factor's effect shows as the slope of the line segments in the plot. The other factor becomes multiple prediction line segments as it varies from one level to another. This factor shows its effect on the response as the vertical separation of the line segments. If the slopes are different for different line segments, it is probably an indication of an interaction effect, i.e., the change in true average response when the level of one factor changes depends on the level of the other factor. If the connected line segments are close to parallel, it is probably an indication of no interaction effect among the factors used in the plot.

The conclusions drawn based on the interaction plots, Figure P-1 through P-22, and the multiple comparison procedures are presented right after each interaction plot. Multiple comparison procedures are used to determine if the differences in the average responses at different factor levels are statistically significant. For space, the tables containing the results of multiple comparison procedures are not presented here.

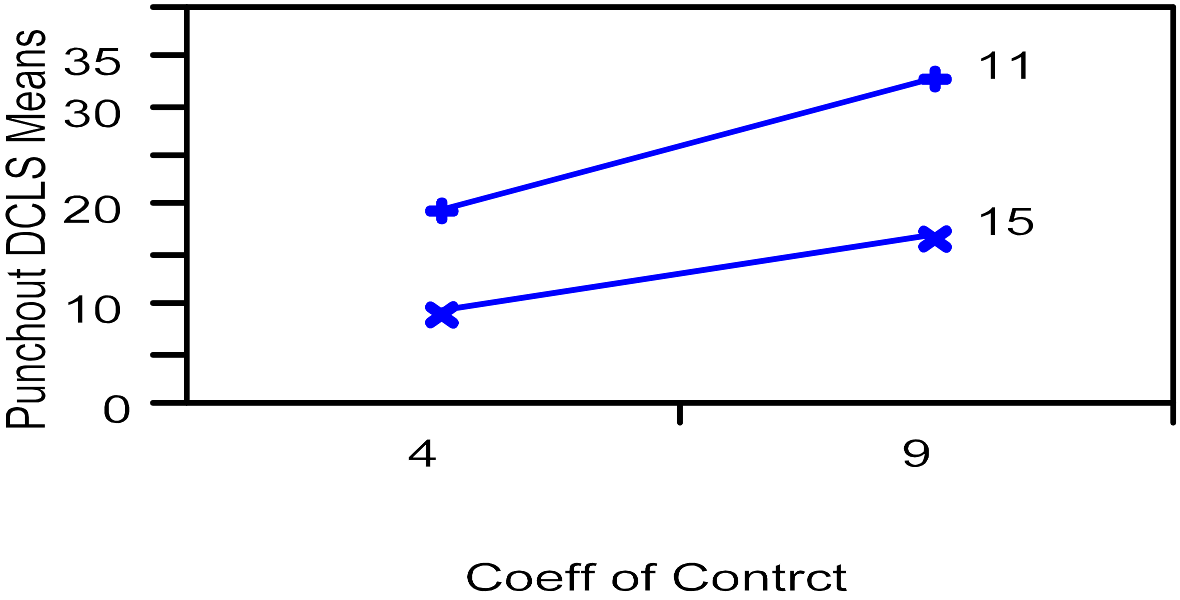

Figure P-1. Interaction Plot for CRC Thickness×Coeff of Contract.

The effect of Coefficient of Contraction is slightly different for each level of CRC Thickness. CRC Thickness level 11 leads to more increase in punchouts than CRC Thickness level 15 when the level of Coefficient of Contraction changes from 4 to 9.

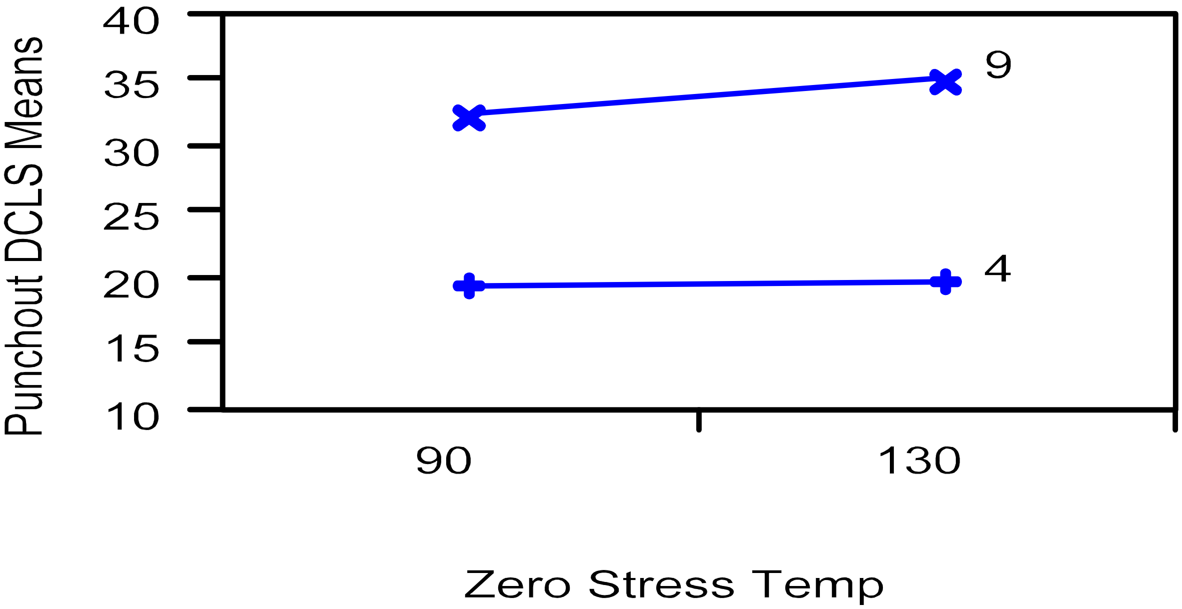

Figure P-2. Interaction Plot for Coeff of Contrct×Zero Stress Temp.

Zero Stress Temperature matters when Coefficient of Contraction is 9, i.e., higher temperature leads to more punchout, but no effect of Zero Stress Temperature is observed when Coefficient of Contraction is 9.

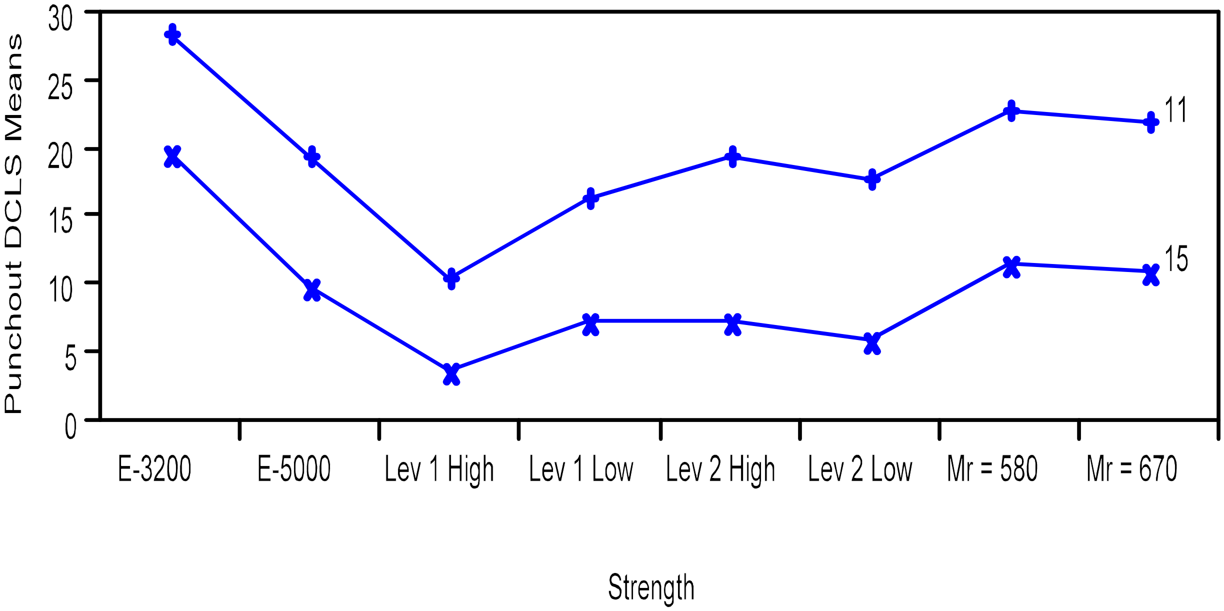

Figure P-3. Interaction Plot for CRC Thickness×Strength.

The effect of CRC Thickness is slightly different for each level of Strength. In general, CRC Thickness level 11 leads to more punchouts than CRC Thickness level 15, regardless of the levels of Strength. However, the magnitude of increase in punchouts when CRC Thickness changes from 15 to 11 is slightly different for each level of Strength.

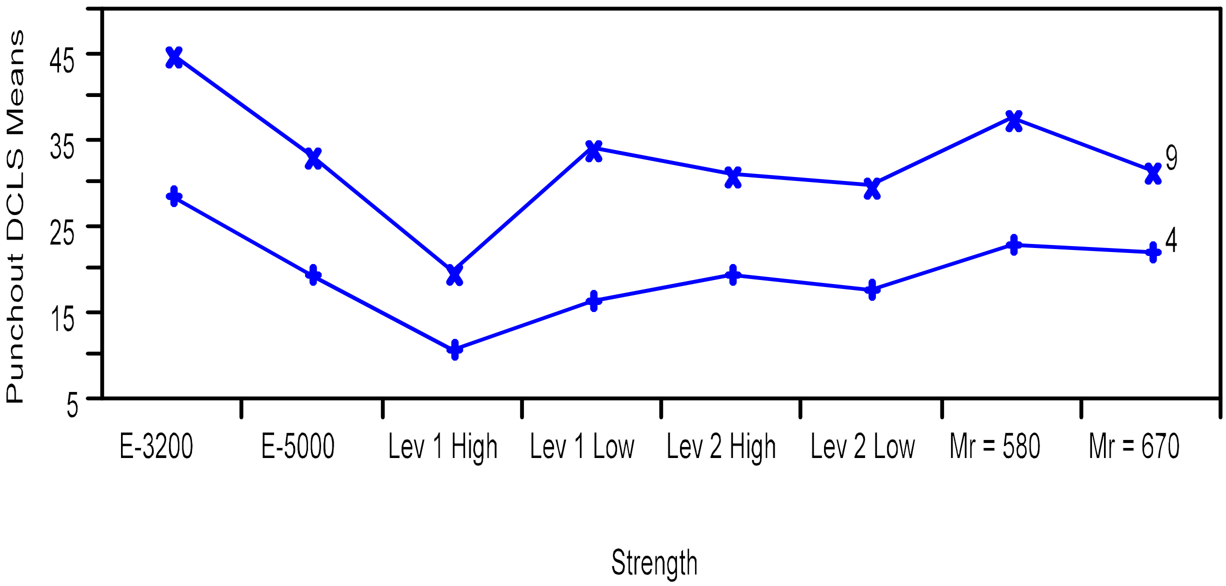

Figure P-4. Interaction Plot for Coeff of Contrct×Strength.

The effect of Coefficient of Contraction is slightly different for each level of Strength. In general, Coefficient of Contraction level 9 leads to more punchouts than Coefficient of Contraction level 4, regardless of the levels of Strength. However, the magnitude of increase in punchouts when Coefficient of Contraction changes from 4 to 9 is slightly different for each level of Strength.

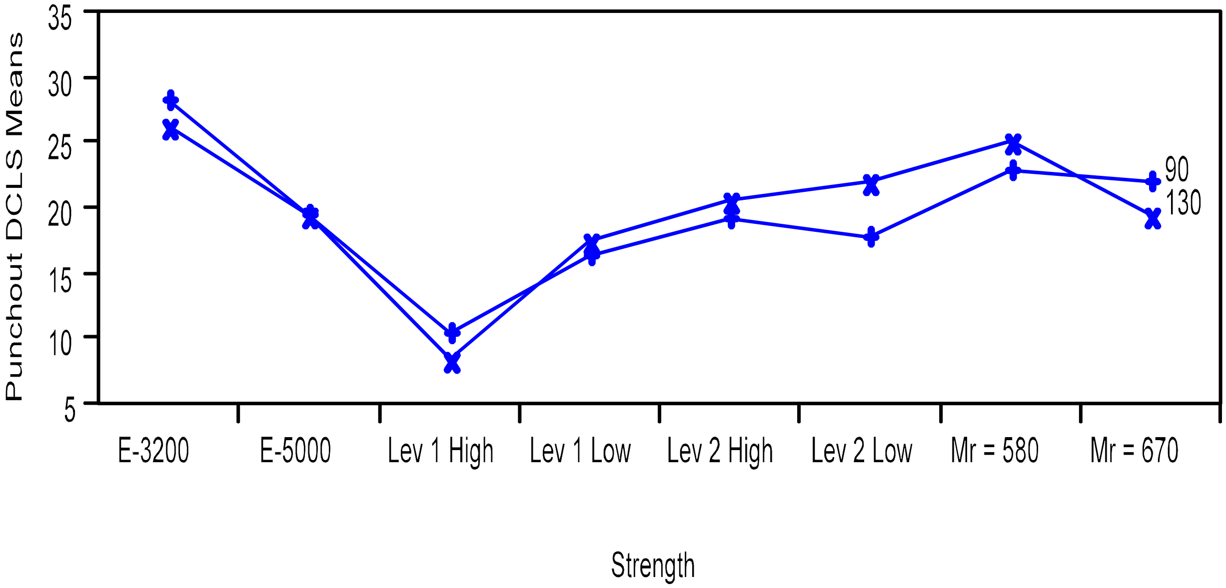

Figure P-5. Interaction Plot for Zero Stress Temp×Strength.

In general, there is no significant difference in punchouts when Zero Stress Temperature changes from 90 to 130 regardless of the levels of Strength. However, the effect of Strength is different for each level of Zero Stress Temperature.

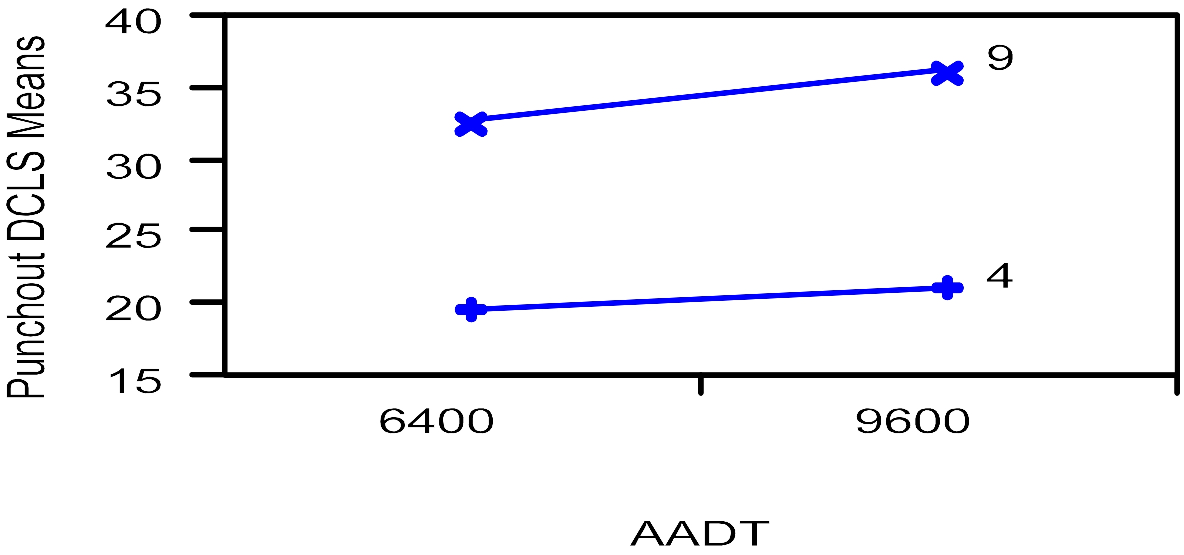

Figure P-6. Interaction Plot for Coeff of Contrct×AADT.

The effect of AADT is slightly different for each level of Coefficient of Contraction. Coefficient of Contraction level 9 leads to slightly more increase in punchouts than Coefficient of Contraction level 4 when AADT changes from 6400 to 9600.

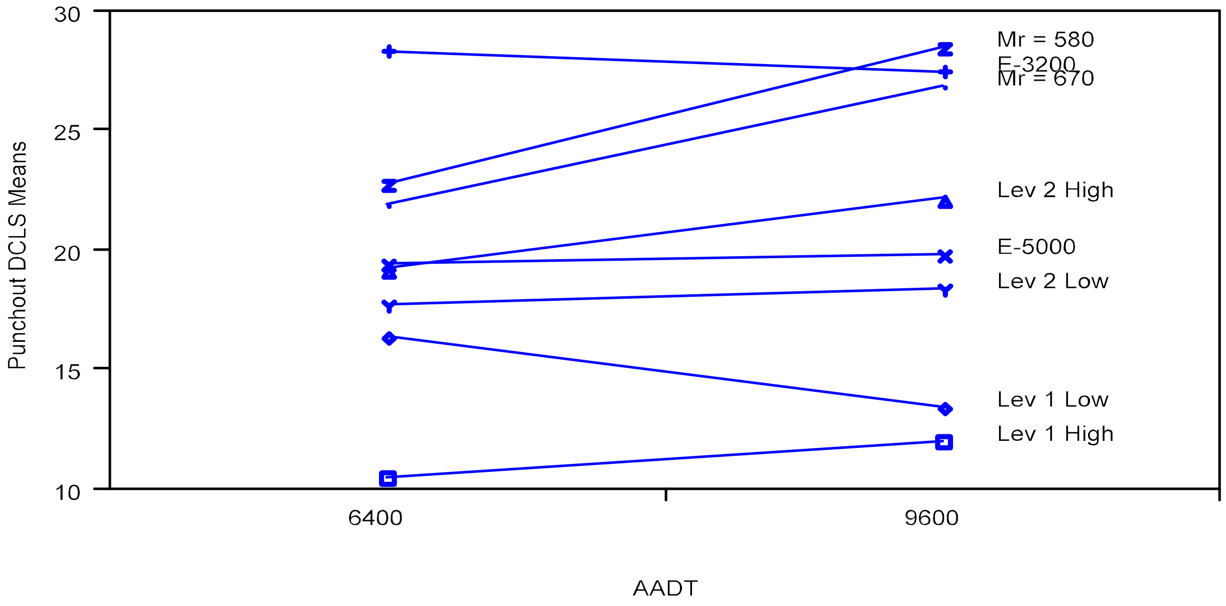

Figure P-7. Interaction Plot for Strength×AADT.

The effect of AADT is different for each level of Strength. Only for the Strength levels Mr=580 and Mr=670, there is a statistically significant effect due to AADT, i.e., AADT 9600 leads to more punchouts than AADT 6400. For the other levels of Strength, the effect of AADT is statistically insignificant, i.e., there is no difference in punchouts whether AADT is 9600 or 6400.

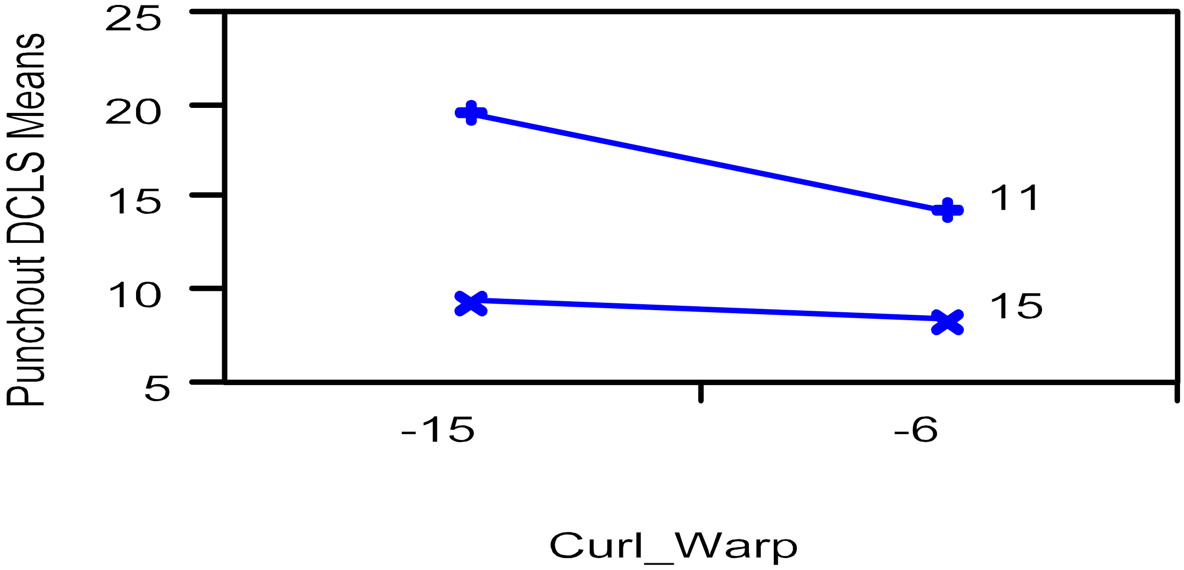

Figure P-8. Interaction Plot for CRC Thickness×Curl_Warp.

The effect of Curl/Warp Temperature Difference is different for each level of CRC Thickness. Curl/Warp Temperature matters when CRC Thickness is 11, i.e., higher Curl/Warp Temperature leads to less punchout, but no effect of Curl/Warp Temperature is observed when CRC Thickness is 15.

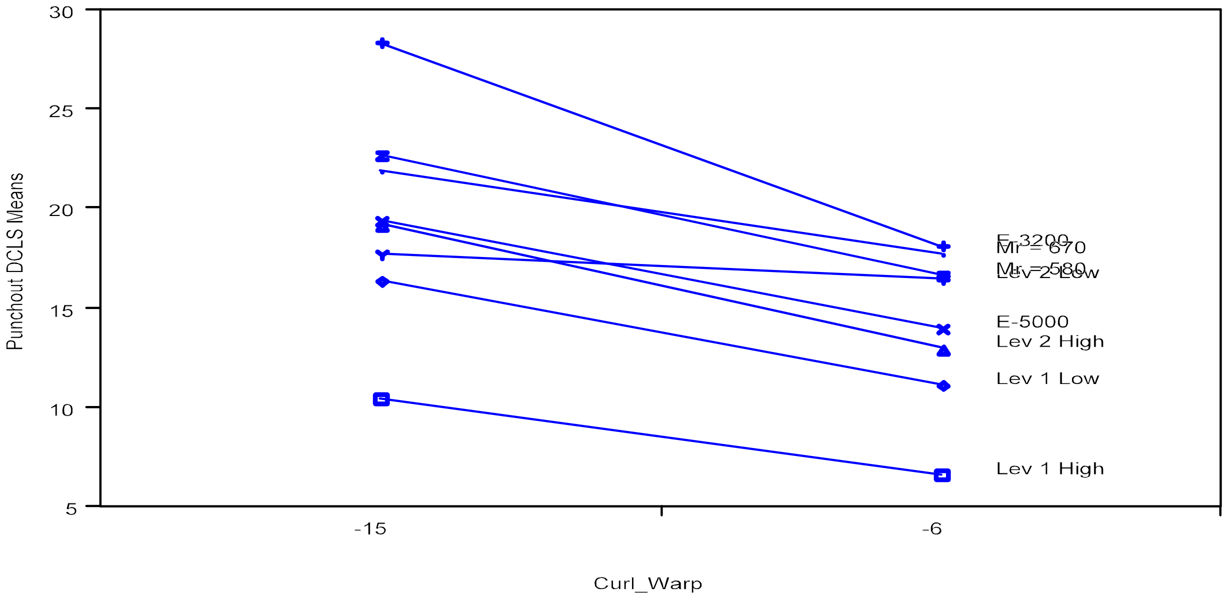

Figure P-9. Interaction Plot for Strength×Curl_Warp.

The effect of Curl/Warp Temperature is different for each level of Strength. Only for the Strength levels, E-3200, E-5000, Mr=580, and Lev 2 High, there is a statistically significant effect due to Curl/Warp Temperature, i.e., Curl/Warp Temperature −6 leads to less punchout than Curl/Warp Temperature −15. For the other levels of Strength, the effect of Curl/Warp Temperature is statistically insignificant, i.e., there is no difference in punchout whether Curl/Warp Temperature is −15 or −6.

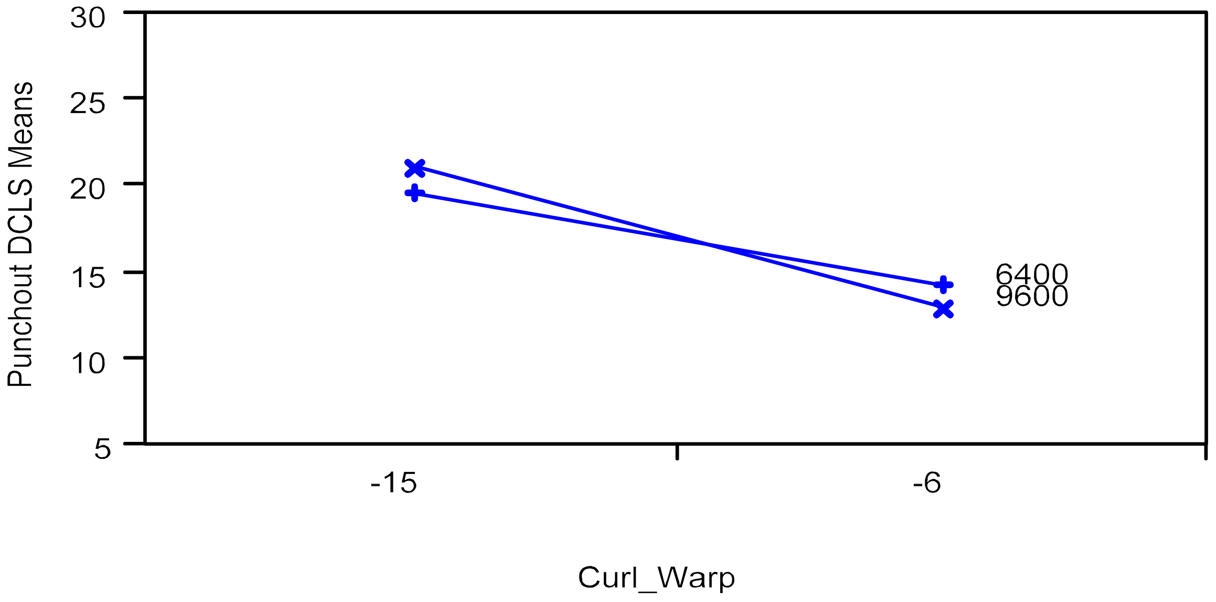

Figure P-10. Interaction Plot for AADT×Curl_Warp.

The effect of Curl/Warp Temperature is slightly different for each level of AADT. AADT 9600 leads to slightly more decrease in punchout than AADT 6400 when Curl/Warp Temperature changes from −15 to −6.

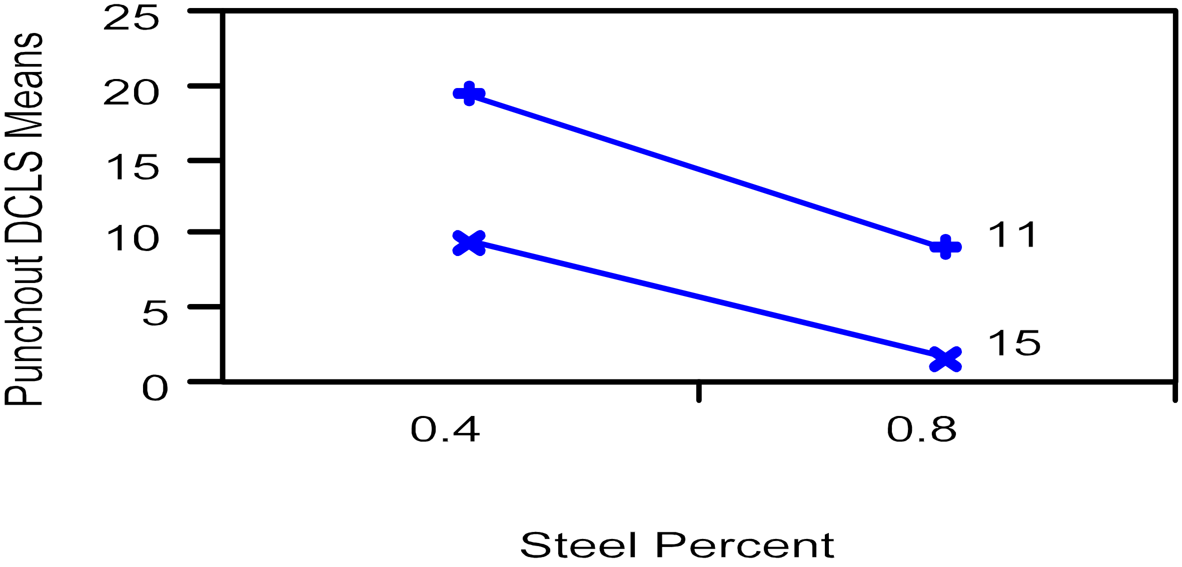

Figure P-11. Interaction Plot for CRC Thickness×Steel Percent.

The effect of Steel Percent is slightly different for each level of CRC Thickness. CRC Thickness 11 leads to slightly more decrease in punchouts than CRC Thickness 15 when Steel Percent increases from 0.4 to 0.8.

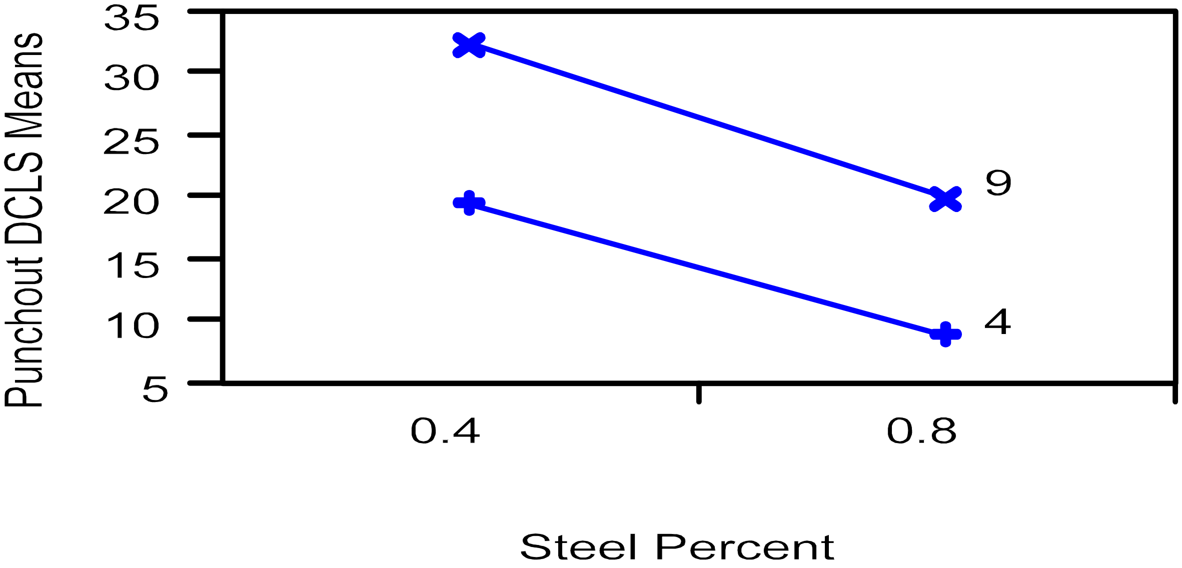

Figure P-12. Interaction Plot for Coeff of Contrct×Steel Percent.

The effect of Steel Percent is slightly different for each level of Coefficient of Contraction. Coefficient of Contraction 9 leads to slightly more decrease in punchouts than Coefficient of Contraction 4 when Steel Percent increases from 0.4 to 0.8.

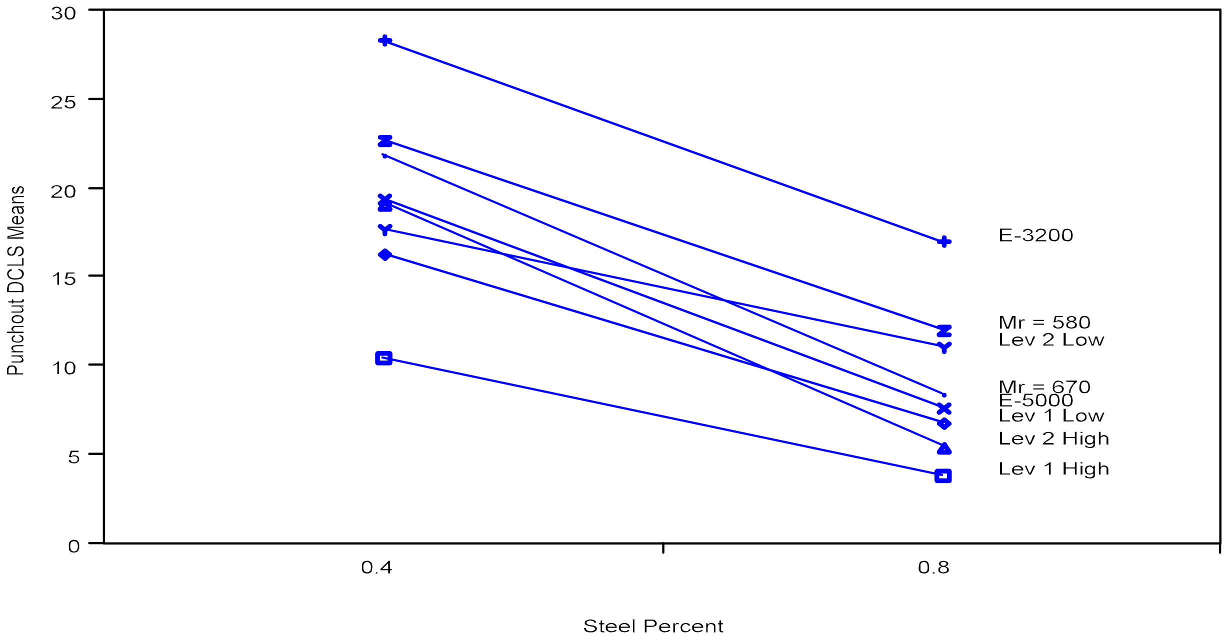

Figure P-13. Interaction Plot for Strength×Steel Percent.

The effect of Steel Percent slightly is different for each level of Strength. In general, punchouts decrease as Steel Percent increases from 0.4 to 0.8 regardless of the levels of Strength. However, the magnitude of decrease is different for each level of Strength. The effect of Steel Percent is largest for Strength Lev 2 High, and is smallest for Lev 2 Low.

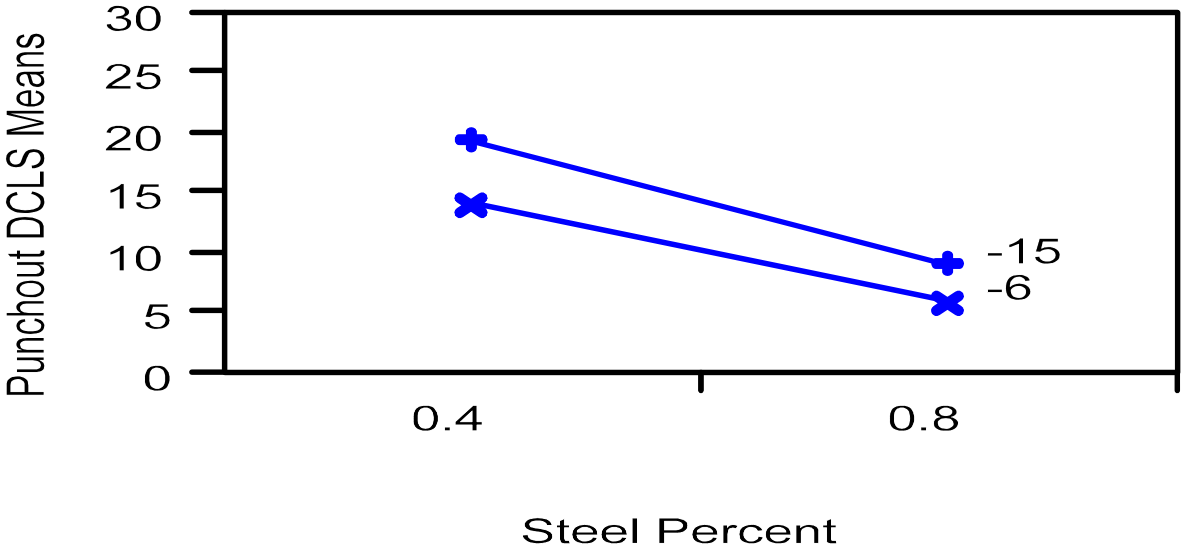

Figure P-14. Interaction Plot for Curl_Warp×Steel Percent.

The effect of Steel Percent on punchouts is slightly larger when the level of Curl/Warp Temperature is −15 than when it is −6. That is, Curl/Warp Temperature −15 leads to slightly more decrease in punchouts than Curl/Warp Temperature −6 when Steel Percent increases from 0.4 to 0.8.

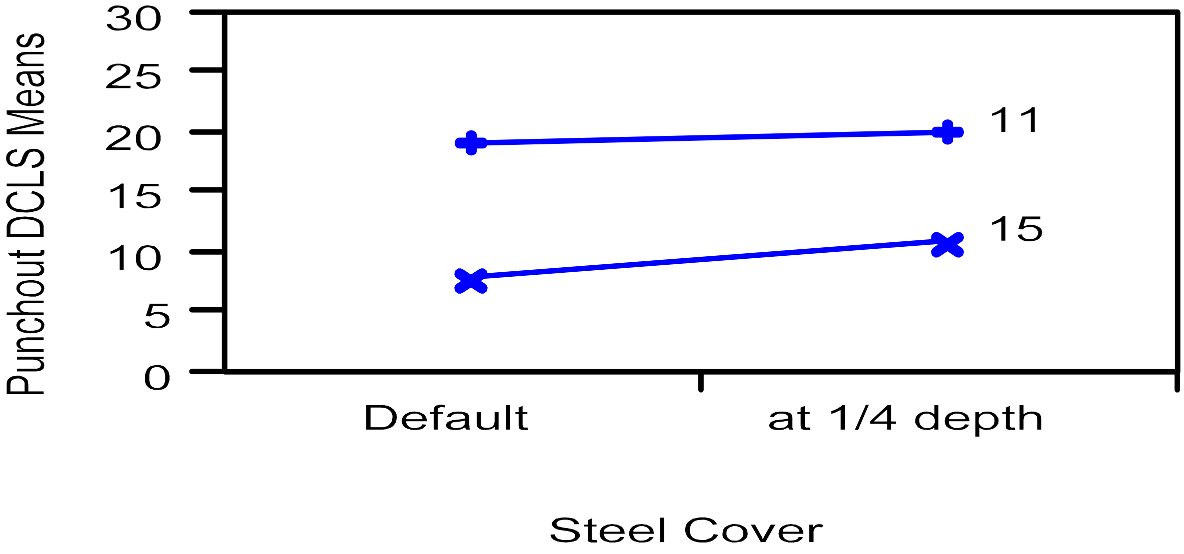

Figure P-15. Interaction Plot for CRC Thickness×Steel Cover.

There is an effect of Steel Cover when CRC Thickness is 15, i.e., punchouts increase as Steel Cover changes from Default to at ¼ depth. However, there is no Steel Cover effect when CRC Thickness is 11.

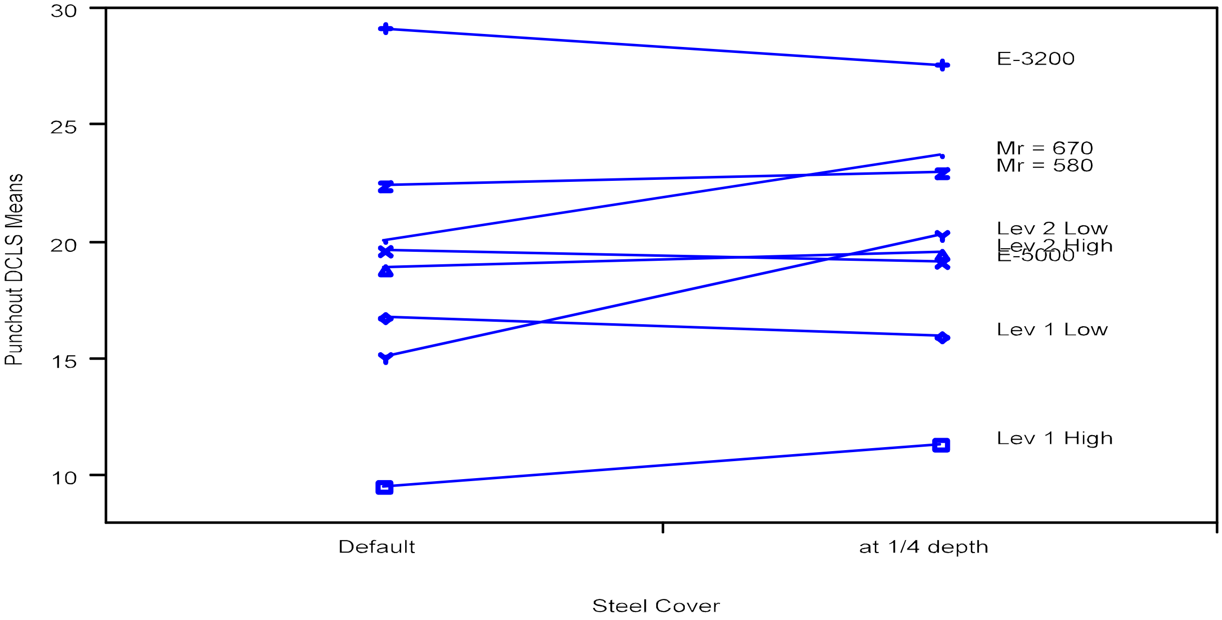

Figure P-16. Interaction Plot for Strength×Steel Cover.

The effect of Steel Cover is different for each level of Strength. Only for Strength Lev 2 Low, there is a statistically significant effect due to Steel Cover, i.e., Steel Cover at ¼ depth leads to more punchouts than Steel Cover Default. For the other levels of Strength, the effect of Steel Cover is statistically insignificant, i.e., whether Steel Cover is Default or at ¼ depth, there is no difference in punchouts.

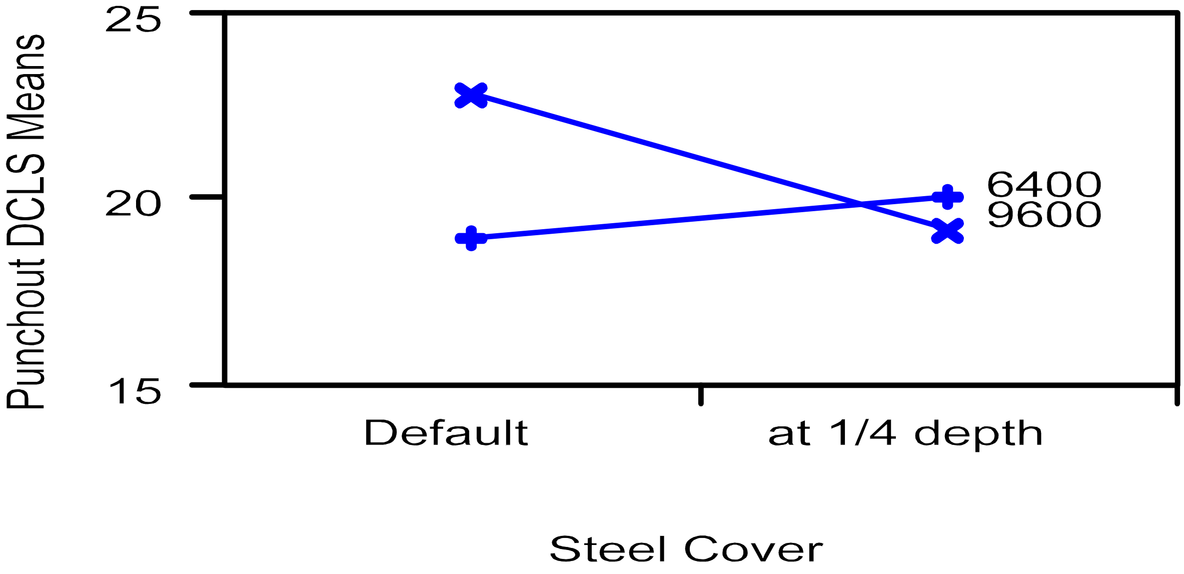

Figure P-17. Interaction Plot for AADT×Steel Cover.

There is an effect of Steel Cover when AADT is 9600, i.e., punchouts decrease as Steel Cover changes from Default to at ¼ depth. However, there is no Steel Cover effect when AADT is 6400. Also, AADT matters only when Steel Cover is Default, i.e., AADT 6400 leads to less punchouts compared to AADT 9600. However, when Steel Cover is at ¼ depth, AADT does not matter, i.e., punchouts are approximately the same for both levels of AADT.

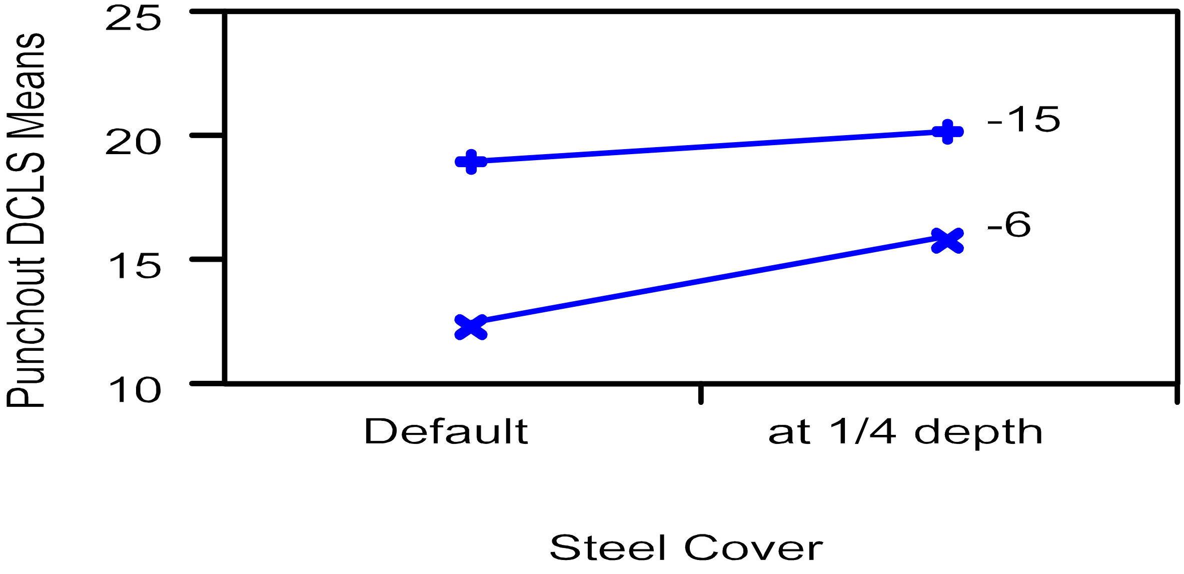

Figure P-18. Interaction Plot for Curl_Warp×Steel Cover.

There is an effect of Steel Cover when Curl/Warp Temperature is −6, i.e., punchout increases as Steel Cover changes from Default to at ¼ depth. However, there is no Steel Cover effect when Curl/Warp Temperature is −15.

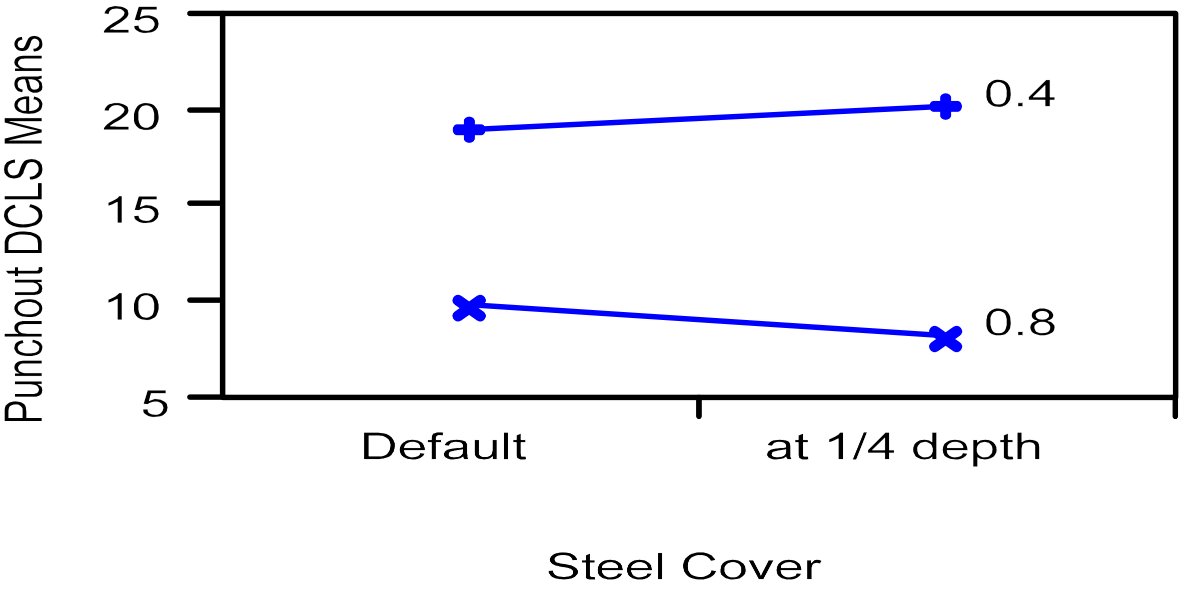

Figure P-19. Interaction Plot for Steel Percent×Steel Cover.

The effect of Steel Percent is slightly different for each level of Steel Cover. The magnitude of decrease in punchouts as Steel Percent increases from 0.4 to 0.8 is larger when Steel Cover is at ¼ depth than when Steel Cover is at Default.

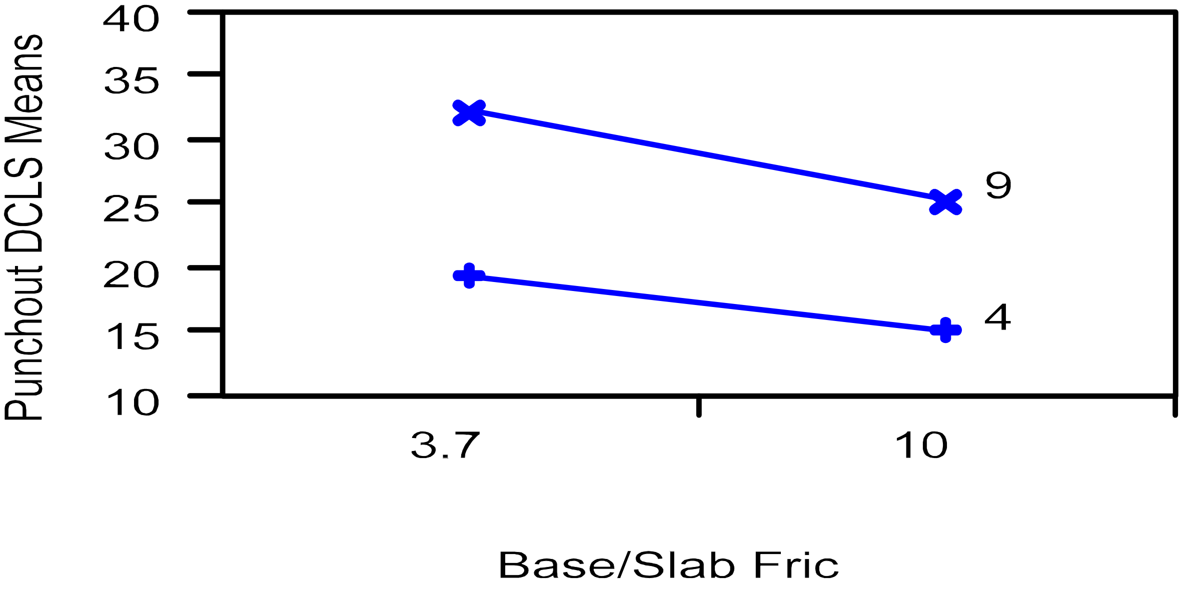

Figure P-20. Interaction Plot for Coeff of Contrct×Base/Slab Fric.

The effect of Coefficient of Contraction is slightly different for each level of Base/Slab Friction. The magnitude of decrease in punchouts as Coefficient of Contraction changes from 9 to 4 is larger when Base/Slab Friction is 3.7 than when Base/Slab Friction is at 10.

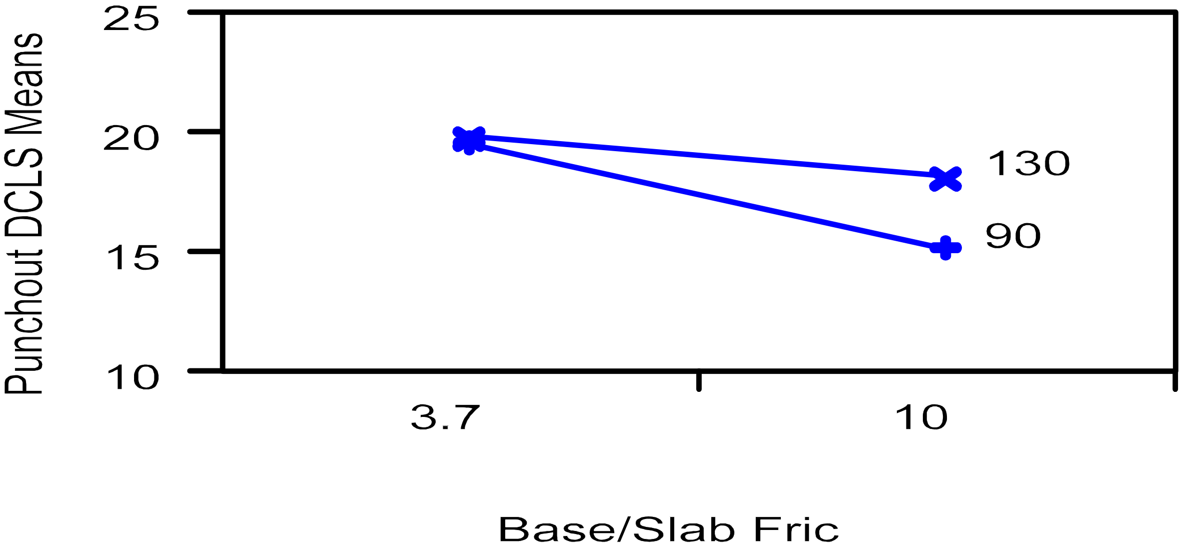

Figure P-21. Interaction Plot for Zero Stress Temp×Base/Slab Fric.

The effect of Base/Slab Friction is slightly different for each level of Zero Stress Temperature. For Zero Stress Temperature 90, Base/Slab Friction 10 leads to less punchouts than Base/Slab Friction 3.7. For Zero Stress Temperature 130, Base/Slab Friction does not matter.

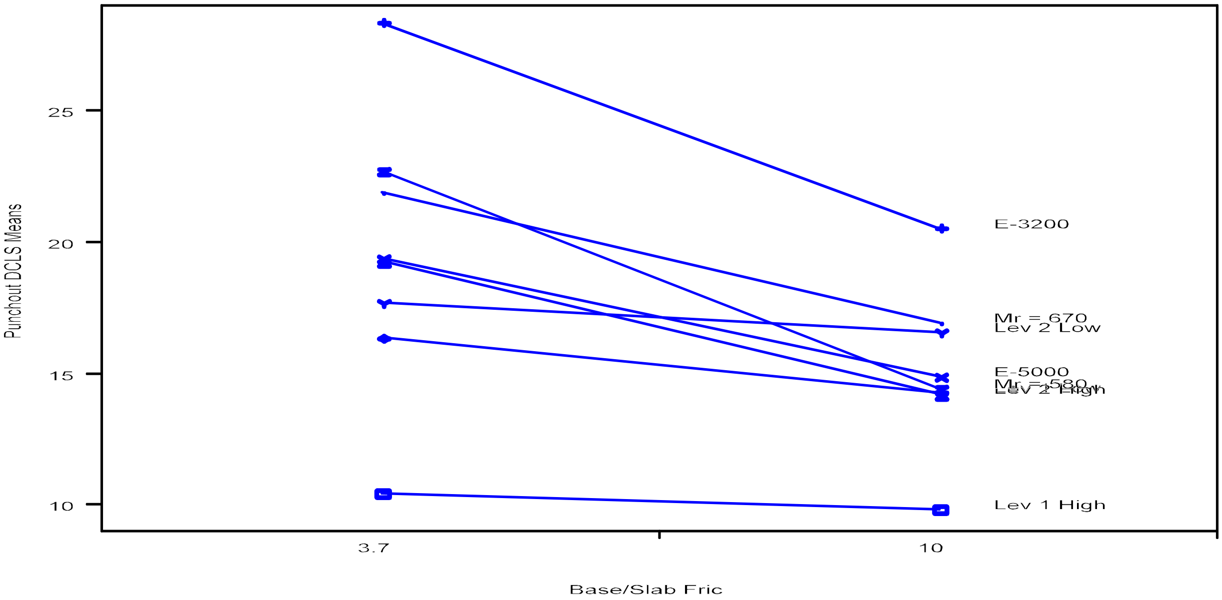

Figure P-22. Interaction Plot for Strength×Base/Slab Fric.

The effect of Base/Slab Friction is different for each level of Strength. Only for the levels of Strength, E-3200 and Mr=580, there is a statistically significant effect due to Base/Slab Friction, i.e., Base/Slab Friction 10 leads to less punchouts than Base/Slab Friction 3.7. For the other levels of strength, the effect of Base/Slab Friction is statistically insignificant, i.e., whether Base/Slab Friction is 3.7 or 10, there is no difference in punchouts.

APPENDIX Q

MULTIPLE VARIABLE ANALYSIS FOR BONDED CONCRETE OVERLAY PAVEMENTS

MULTIPLE VARIABLE ANALYSIS - BONDED CONCRETE OVERLAY

Q.1 MULTIPLE VARIABLE ANALYSIS - BONDED CONCRETE OVERLAY

The computer experimental data for punchout under various factor-level combinations for each of the Dry-Cold and the Wet-Warm region were analyzed to identify the important factors that affect punchout. Tables Q-1 and Q-2 contain the factors and their corresponding levels investigated.

Table Q-1. Factors for the Dry-Cold Region.

<table>
<tr><th>Factors</th><th colspan="4">Levels</th></tr>
<tr><td>OL Thick</td><td colspan="2">5</td><td colspan="2">3</td></tr>
<tr><td>CRC Thick</td><td colspan="2">15</td><td colspan="2">11</td></tr>
<tr><td>Curl/Warp</td><td colspan="2">-15</td><td colspan="2">-6</td></tr>
<tr><td>Mix Properties</td><td colspan="2">800</td><td colspan="2">130</td></tr>
<tr><td>Mean Crack Space</td><td colspan="2">72</td><td colspan="2">24</td></tr>
<tr><td>OL Coeff Contract</td><td colspan="2">9</td><td colspan="2">4</td></tr>
<tr><td>OL Poisson's Ratio</td><td colspan="2">0.2</td><td colspan="2">0.1</td></tr>
<tr><td>Strength-OL</td><td>2-Hi</td><td colspan="2">Med</td><td>Low</td></tr>
<tr><td>LS Resilient Modulus</td><td colspan="2">300</td><td colspan="2">50</td></tr>
</table>

Note: For Strength-OL, 2-Hi denotes 18/25/50/55/1.5, Med denotes 15/20/40/45/1.35, and Low denotes 13/175/32/35/1.2.

Table Q-2. Factors for the Wet-Warm Region.

<table>
<tr><th>Factors</th><th colspan="4">Levels</th></tr>
<tr><td>OL Thick</td><td colspan="2">5</td><td colspan="2">3</td></tr>
<tr><td>CRC Thick</td><td colspan="2">15</td><td colspan="2">11</td></tr>
<tr><td>Curl/Warp</td><td colspan="2">-15</td><td colspan="2">-6</td></tr>
<tr><td>OL Coeff Contract</td><td colspan="2">9</td><td colspan="2">4</td></tr>
<tr><td>Strength-OL</td><td>2-Hi</td><td colspan="2">Med</td><td>Low</td></tr>
</table>

Note: For Strength-OL, 2-Hi denotes 18/25/50/55/1.5, Med denotes 15/20/40/45/1.35, and Low denotes 13/175/32/35/1.2.

Q.2 ANALYSIS OF DRY-COLD BONDED CONCRETE OVERLAY

Analysis of Variance (ANOVA) was employed to analyze the data. For the Dry-Cold region, models with OL Thickness, CRC Thickness, Curl/Warp, Mix Properties, Mean Crack Space, OL Coefficient of Contraction, OL Poisson's Ratio, Strength-OL, and LS Resilient Modulus as main effects and all possible two-way interactions were explored. Table Q-3 contains the analysis of variance table for the model in Table Q-4, which shows the model is significant at $\alpha = 0.05$. There were originally 36 possible two-way interactions in addition to the 9 main effects. After removing the insignificant interactions from the model, a model in Table Q-4 was selected as an adequate model with respect to the terms included. All of the 14 interaction effects retained in the model were statistically significant at the level α = 0.05.

Table Q-3. Analysis of Variance for Dry-Cold Region.

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	28	909611.66	32486.1	88.8955
Error	67	24484.61	365.4	**Prob > F**
C. Total	95	934096.27		<.0001

Table Q-4. Effect Tests for Dry-Cold Region.

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Strength-OL	2	2	75662.70	103.52	<.0001
OL Thick	1	1	32467.55	88.84	<.0001
OL Poisson's Ratio	1	1	6.38	0.018	0.8953
OL Coeff Contract	1	1	315775.03	864.09	<.0001
Mix Properties	1	1	433.30	1.19	0.2801
CRC Thick	1	1	94913.83	259.72	<.0001
Curl/Warp	1	1	10907.92	29.85	<.0001
Mean Crack Space	1	1	166076.68	454.45	<.0001
LS Resilient Modulus	1	1	932.17	2.55	0.1149
Strength-OL×OL Thick	2	2	3205.44	4.39	0.0162
Strength-OL×OL Poisson's Ratio	2	2	3153.41	4.31	0.0173
Strength-OL×OL Coeff Contract	2	2	45266.94	61.93	<.0001
OL Coeff Contract×Mix Properties	1	1	4788.09	13.10	0.0006
Strength-OL×CRC Thick	2	2	7551.01	10.33	0.0001
OL Thick×CRC Thick	1	1	4611.42	12.62	0.0007
OL Coeff Contract×CRC Thick	1	1	18610.89	50.93	<.0001
Mix Properties×CRC Thick	1	1	1913.22	5.24	0.0253
OL Poisson's Ratio×Curl/Warp	1	1	2463.71	6.74	0.0116
OL Coeff Contract×Curl/Warp	1	1	5420.82	14.83	0.0003
OL Thick×Mean Crack Space	1	1	12479.55	34.15	<.0001
OL Coeff Contract×Mean Crack Space	1	1	62648.34	171.43	<.0001
CRC Thick×Mean Crack Space	1	1	32387.87	88.63	<.0001
OL Poisson's Ratio×LS Resilient Modulus	1	1	1865.76	5.11	0.0271

Since there are significant interaction effects (joint effects of two factors), the individual factor effects (main effects) can only be assessed conditional on each level of the other factor. Plots for the statistically significant interaction effects are presented in Figures Q-1 through Q-14. The conclusions drawn based on the interaction plots and the multiple comparison procedures are presented right after each interaction plot. The explanations of interaction plots and multiple comparison procedures were given in the analysis for CRCP pavements. For space, the tables containing the results of multiple comparison procedures are not presented here.

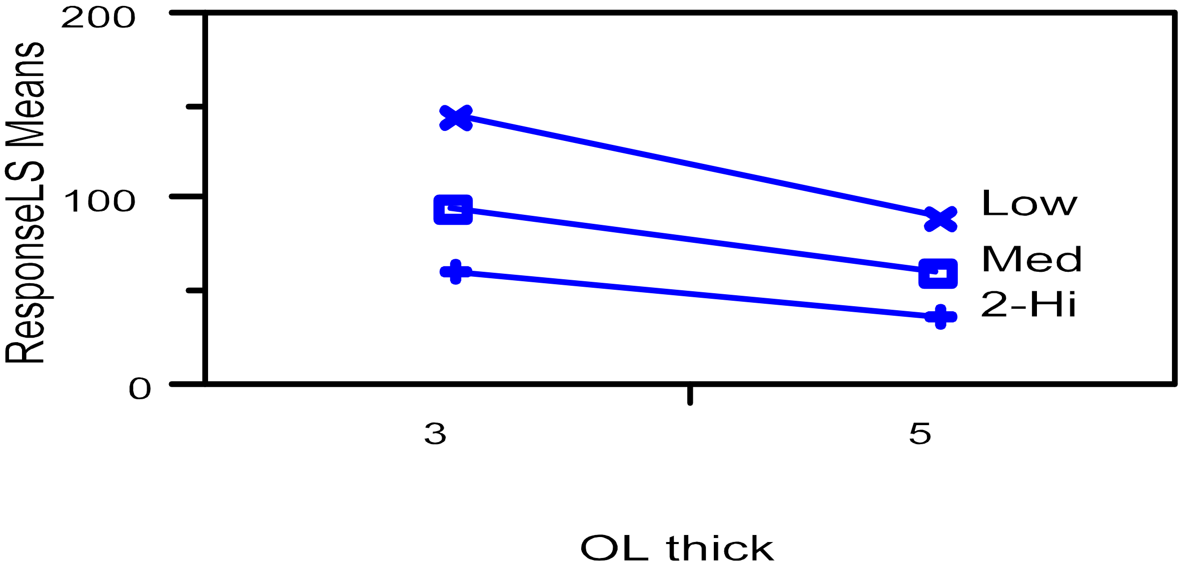

Figure Q-1. Interaction Plot for Strength-OL×OL Thick (Dry-Cold).

The effect of OL Thickness is slightly different for each level of Strength-OL. Strength-OL level Low leads to slightly more decrease in punchouts than Strength-OL levels Med and 2-Hi when the level of OL Thickness changes from 3 to 5.

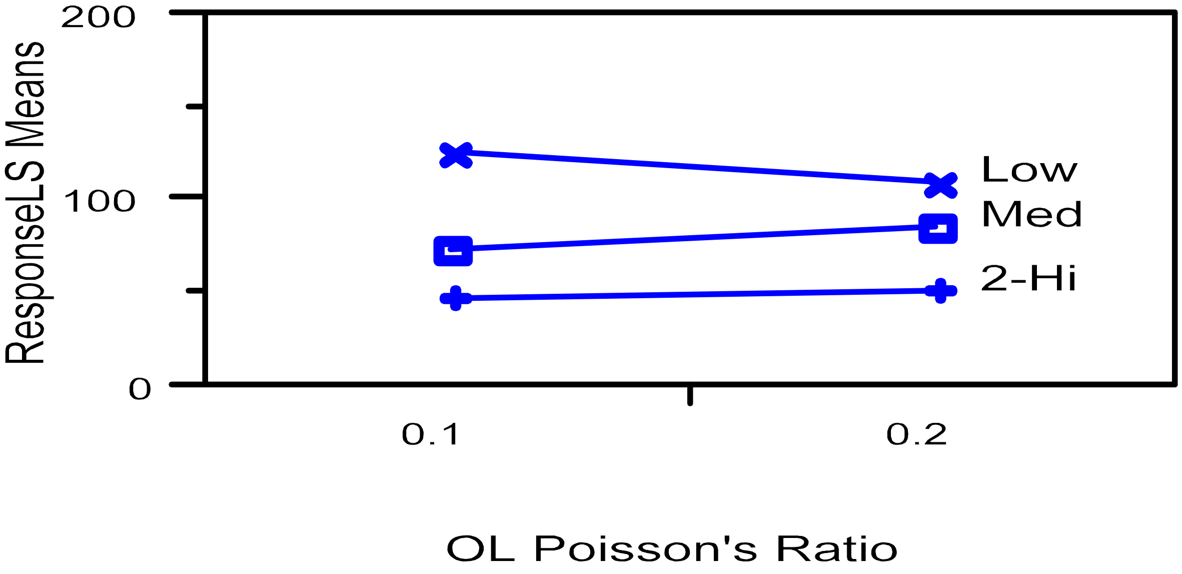

Figure Q-2. Interaction Plot for Strength-OL×OL Poisson's Ratio (Dry-Cold).

There is no significant effect of OL Poisson's Ratio on punchouts regardless of the levels of Strength-OL. However, there is an effect of Strength-OL on punchouts, and the effect is different for each level of OL Poisson's Ratio. For instance, the magnitude of increase in punchouts when Strength-OL changes from Med to Low is larger for OL Poisson's Ratio level 0.1 than for 0.2.

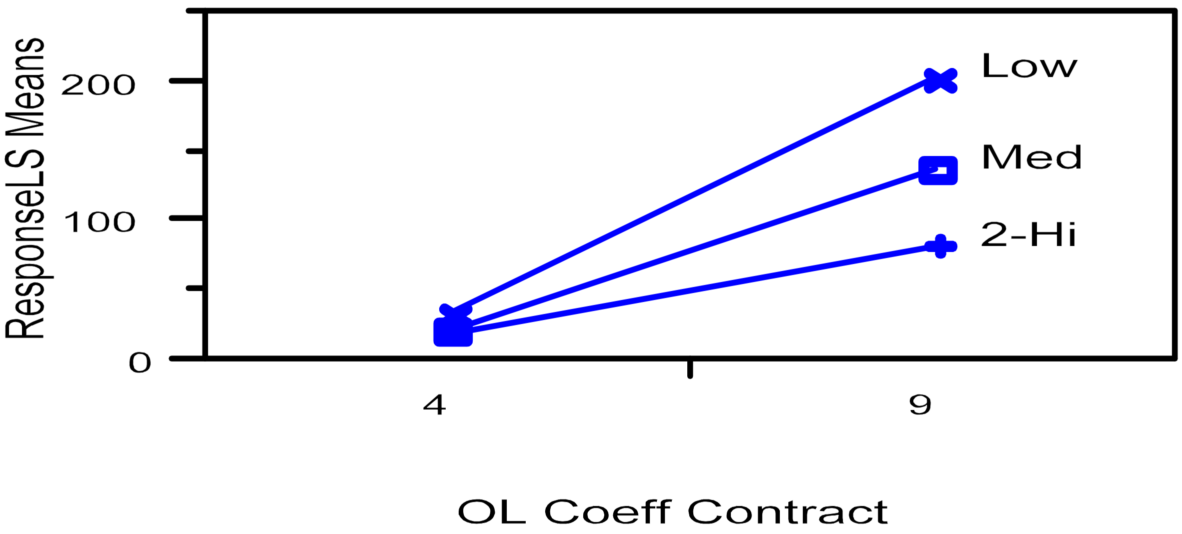

Figure Q-3. Interaction Plot for Strength-OL×OL Coeff Contract (Dry-Cold).

Strength-OL matters when OL Coefficient of Contraction is 9, i.e., Strength-OL Low leads to the most punchouts and Strength-OL 2-Hi leads to the least punchouts. However, when OL Coefficient of Contraction is 4, there is no difference in the mean punchouts for the three different levels of Strength-OL. In general, OL Coefficient of Contraction level 9 leads to more punchouts than OL Coefficient of Contraction level 4, regardless of the levels of Strength-OL. However, the magnitude of increase in punchouts when OL Coefficient of Contraction changes from 4 to 9 is different for each level of Strength-OL.

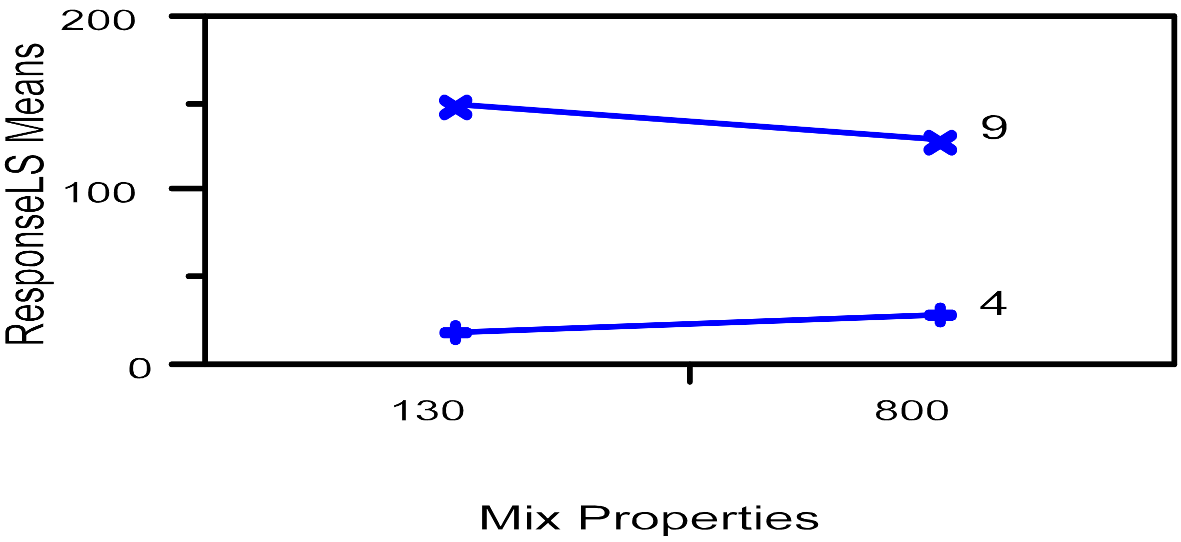

Figure Q-4. Interaction Plot for OL Coeff Contract×Mix Properties.

The effect of Mix Properties is slightly different for each level of OL Coefficient of Contraction. The level of Mix Properties 800 leads to slightly less punchouts than level 130 when OL Coefficient of Contraction is 9. However, no difference in mean punchouts due to change in Mix Properties is observed when OL Coefficient of Contraction is 4. In general, OL Coefficient of Contraction 9 leads to more punchouts than OL Coefficient of Contraction level 4, regardless of the levels of Mix Properties.

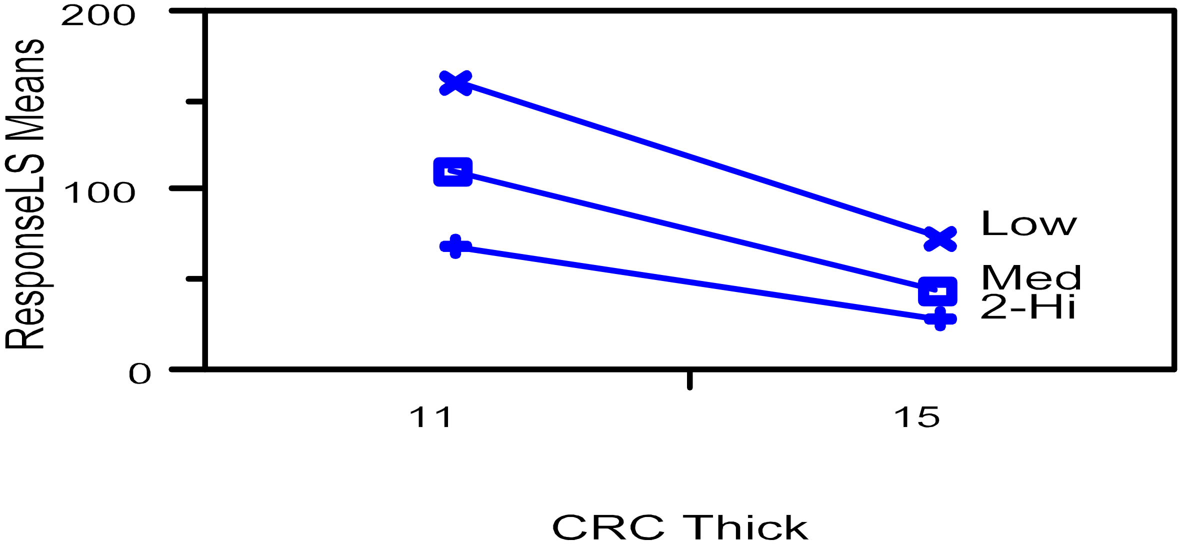

Figure Q-5. Interaction Plot for Strength-OL×CRC Thick (Dry-Cold).

In general, higher CRC Thickness leads to less punchout regardless of the levels of Strength-OL. However, the effect of Strength-OL is different for each level of CRC Thickness. When the level of CRC Thickness is 11, Strength-OL Low leads to the most punchout and Strength-OL 2-Hi leads to the least punchout. When CRC Thickness is 15, however, there is no significant difference in punchouts between Strength-OL Med and Strength-OL 2-Hi (although Strength-OL Low still leads to more punchouts than the other two levels of Strength-OL).

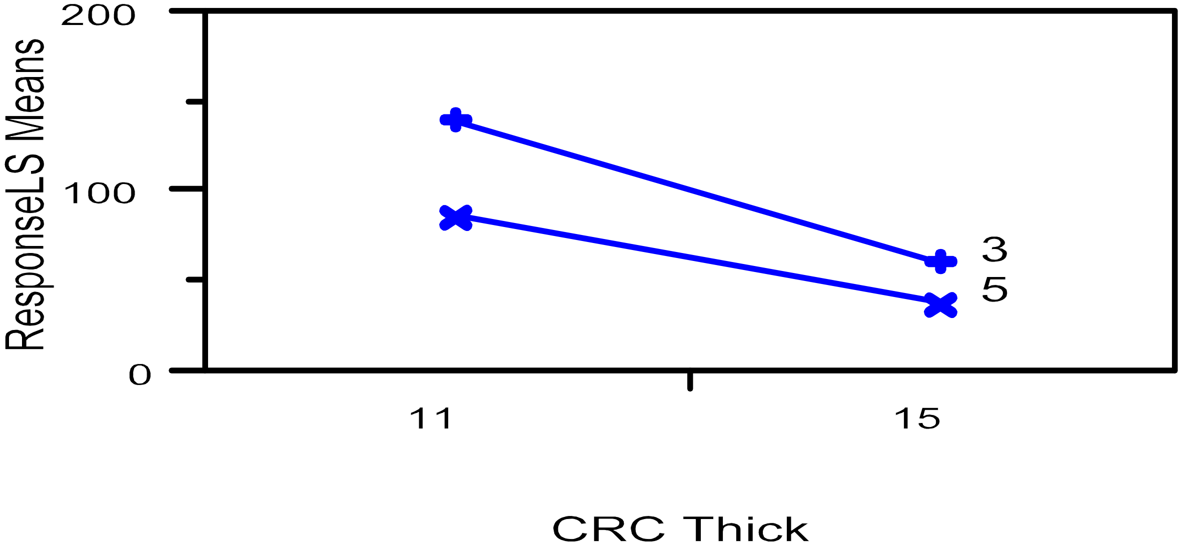

Figure Q-6. Interaction Plot for OL Thick×CRC Thick (Dry-Cold).

The effect of CRC Thickness is slightly different for each level of OL Thickness. OL Thickness level 3 is associated with slightly more decrease in punchouts than OL Thickness level 5 is when CRC Thickness changes from 11 to 15.

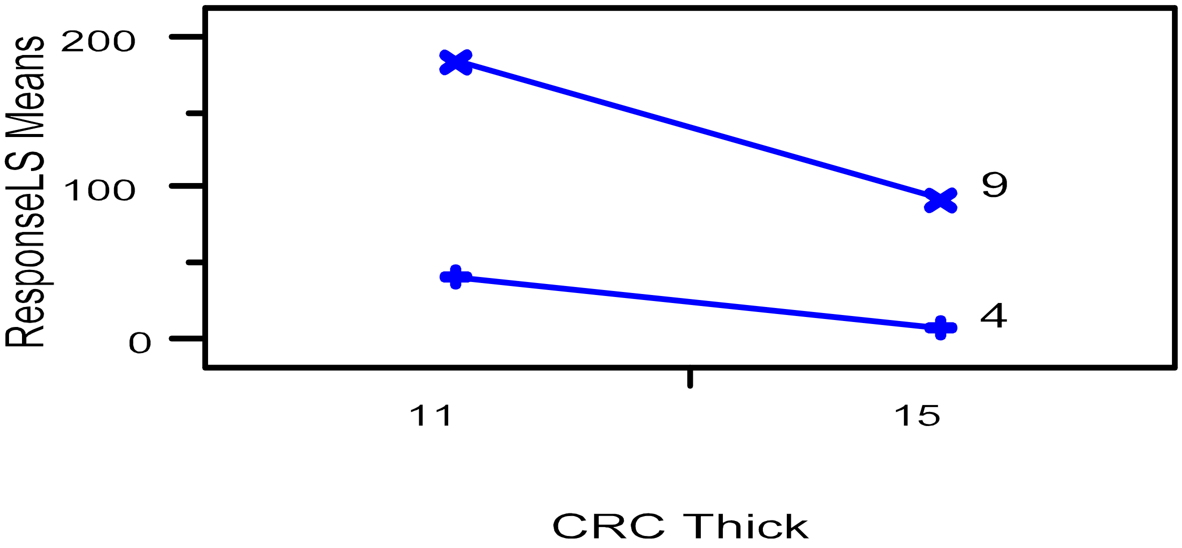

Figure Q-7. Interaction Plot for OL Coeff Contract×CRC Thick (Dry-Cold).

The effect of CRC Thickness is slightly different for each level of OL Coefficient of Contraction. OL Coefficient of Contraction level 9 is associated with slightly more decrease in punchouts than OL Coefficient of Contraction level 4 is when CRC Thickness changes from 11 to 15.

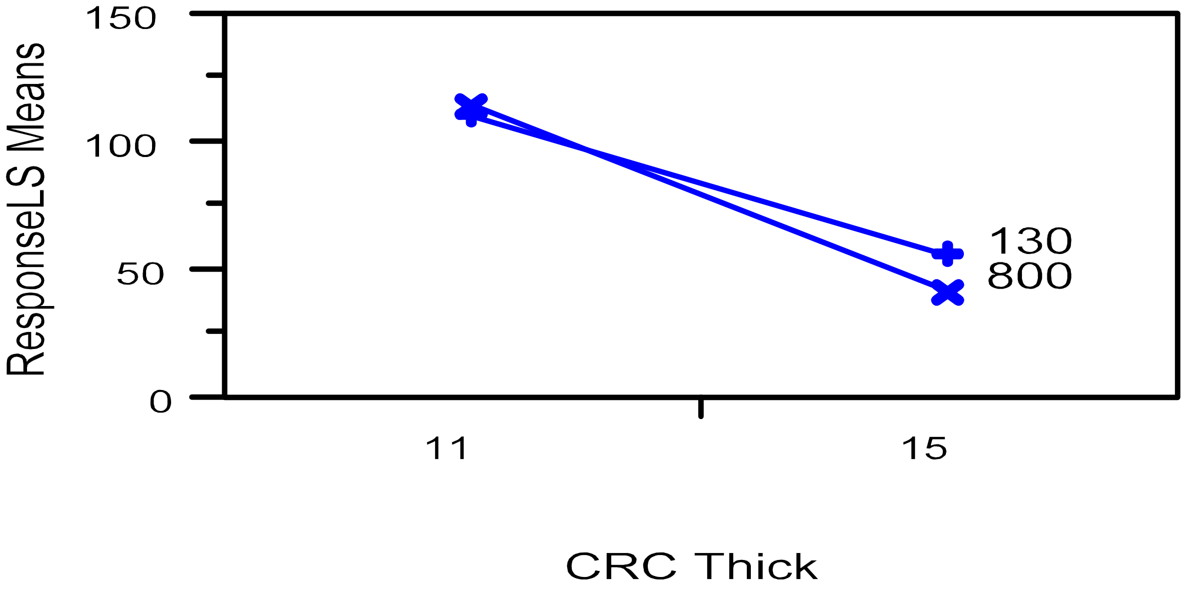

Figure Q-8. Interaction Plot for Mix Properties×CRC Thick (Dry-Cold).

The effect of CRC Thickness is slightly different for each level of Mix Properties. Mix Properties level 800 is associated with more decrease in punchouts than Mix Properties level 130 is when CRC Thickness changes from 11 to 15.

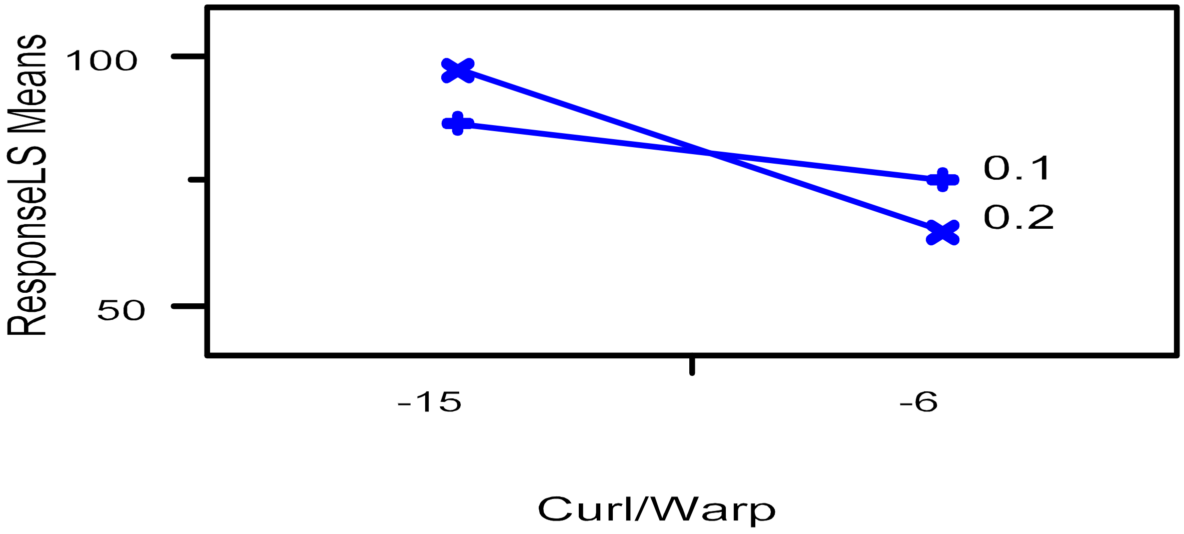

Figure Q-9. Interaction Plot for OL Poisson's Ratio×Curl/Warp (Dry-Cold).

The effect of Curl/Warp is different for each level of OL Poisson's Ratio. Only for OL Poisson's Ratio level 0.2, there is a statistically significant effect due to Curl/Warp, i.e., Curl/Warp −6 leads to less punchouts than Curl/Warp −15 when OL Poisson's Ratio is 0.2. For OL Poisson's Ratio level 0.1, the effect of Curl/Warp is statistically insignificant, i.e., there is no difference in punchouts whether Curl/Warp is −15 or −6 when OL Poisson's Ratio is 0.1.

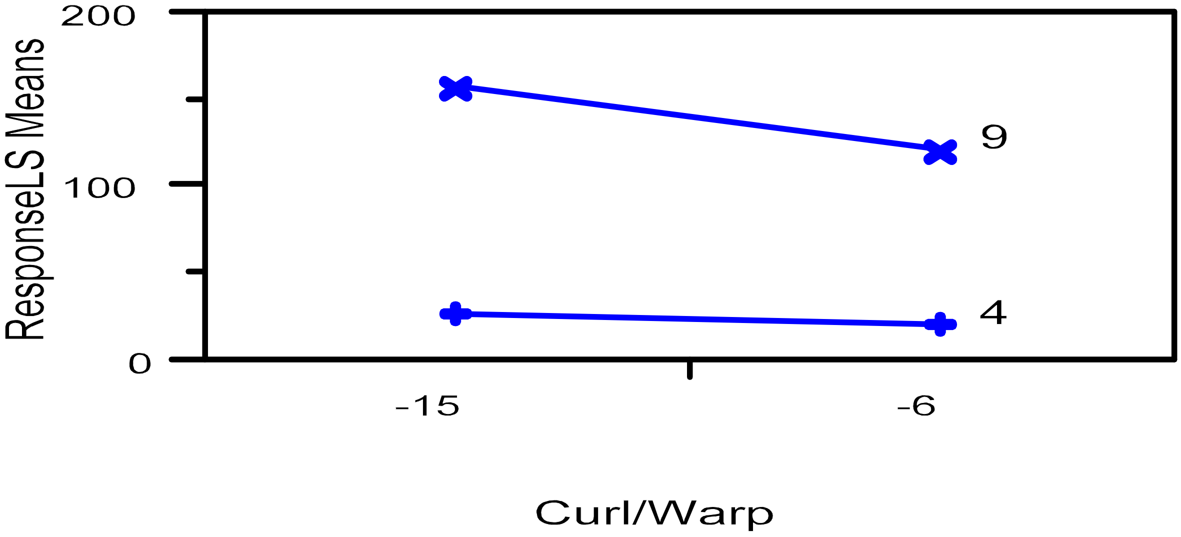

Figure Q-10. Interaction Plot for OL Coeff Contract×Curl/Warp (Dry-Cold).

In general, higher OL Coefficient of Contraction leads to more punchouts although the magnitude of increase in punchouts (when OL Coefficient of Contraction changes from 4 to 9) is slightly different for each level of Curl/Warp. The effect of Curl/Warp is also different for each level of OL Coefficient of Contraction. Curl/Warp −6 leads to less punchouts than Curl/Warp −15 when OL Coefficient of Contraction is 9. There is no significant difference in punchouts whether Curl/Warp is −15 or −6 when OL Coefficient of Contraction is 4.

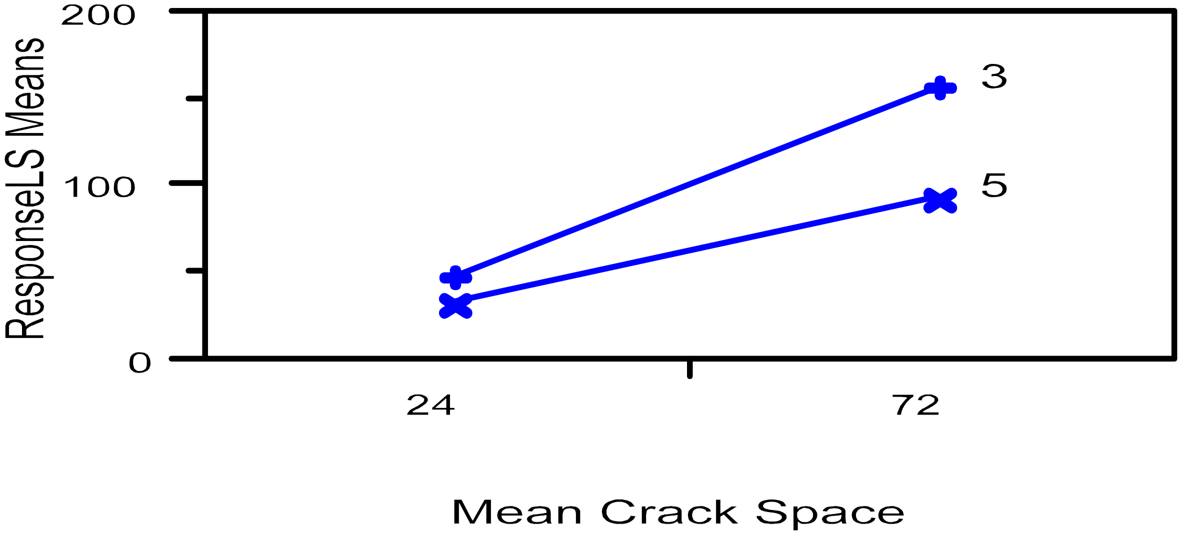

Figure Q-11. Interaction Plot for OL Thick×Mean Crack Space (Dry-Cold).

In general, higher Mean Crack Space leads to more punchouts regardless of the levels of OL Thickness. The effect of OL Thickness is, however, different for each level of Mean Crack Space. For Mean Crack Space level 72, OL Thickness 3 leads to more punchouts than OL Thickness 5 does. For Mean Crack Space level 24, there is no significant difference in punchouts whether OL Thickness is 3 or 5.

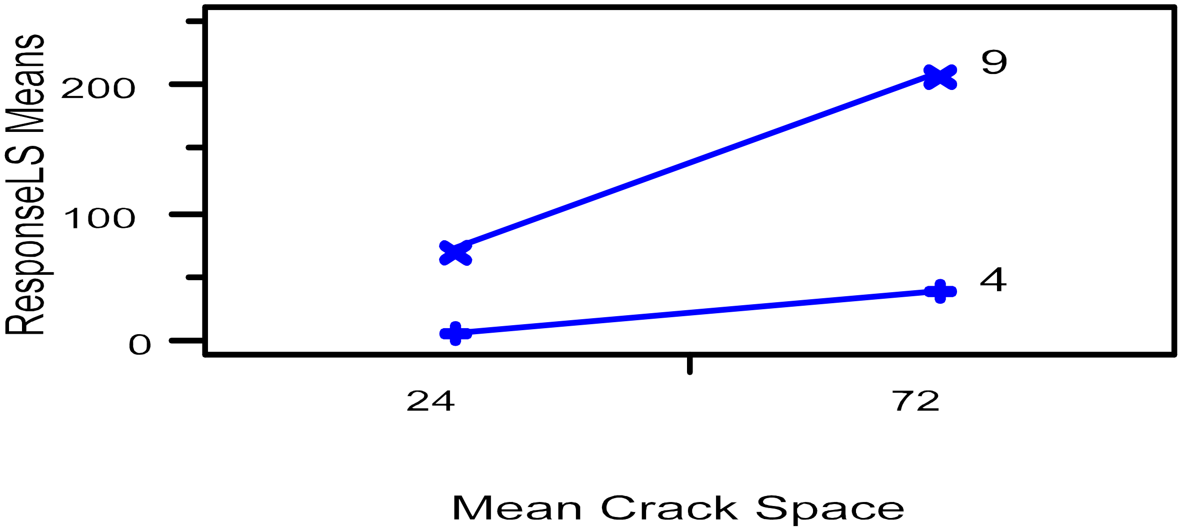

Figure Q-12. Interaction Plot for OL Coeff Contract×Mean Crack Space (Dry-Cold).

In general, OL Coefficient of Contraction level 9 leads to more punchouts than OL Coefficient of Contraction level 4 does. However, the magnitude of increase in punchouts (when OL Coefficient of Contraction changes from 4 to 9) is larger for Mean Crack Space level 72 than for Mean Crack Space level 24. Likewise, Mean Crack Space level 72 leads to more punchouts than Mean Crack Space level 24 does. The magnitude of increase in punchouts (when Mean Crack Space changes from 24 to 72) is larger for OL Coefficient of Contraction level 9 than for OL Coefficient of Contraction level 4.

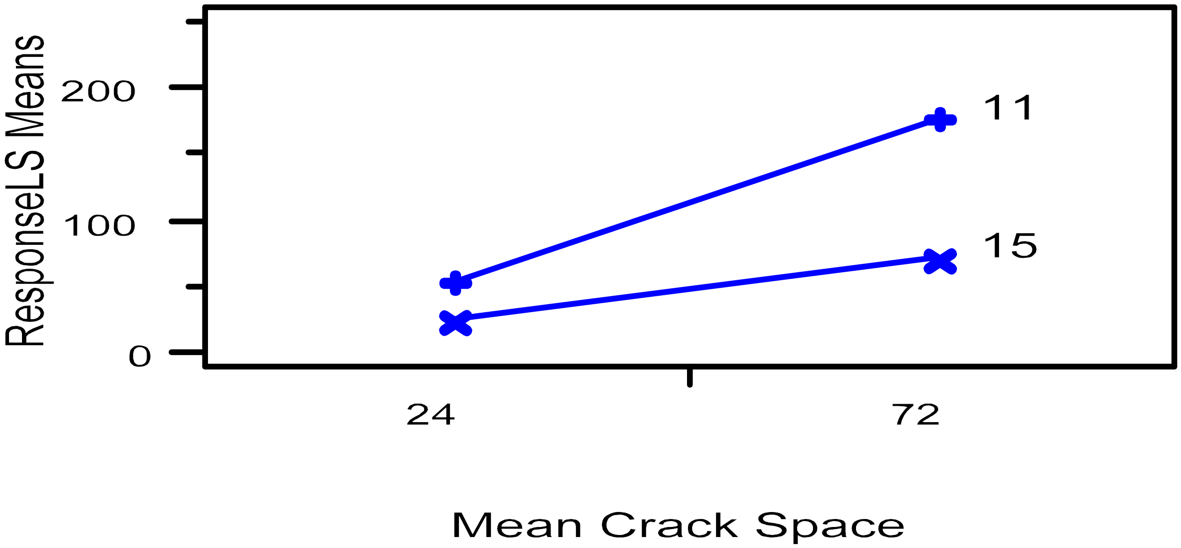

Figure Q-13. Interaction Plot for CRC Thick×Mean Crack Space (Dry-Cold).

In general, CRC Thickness level 11 leads to more punchouts than CRC Thickness level 15 does regardless of the level of Mean Crack Space. However, the magnitude of increase in punchouts (when CRC Thickness changes from 15 to 11) is larger for Mean Crack Space level 72 than for

Mean Crack Space level 24. Likewise, Mean Crack Space level 72 leads to more punchouts than Mean Crack Space level 24 does. The magnitude of increase in punchouts (when Mean Crack Space changes from 24 to 72) is larger for CRC Thickness level 11 than for CRC Thickness level 15.

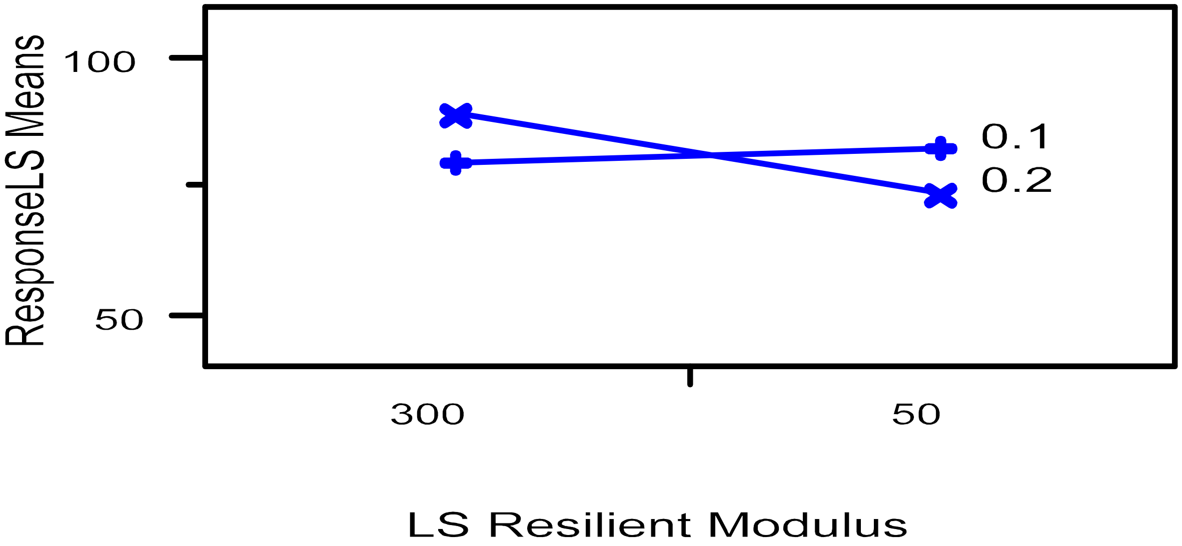

Figure Q-14. Interaction Plot for OL Poisson's Ratio×LS Resilient Modulus (Dry-Cold).

Lower LS Resilient Modulus leads to slightly less punchouts when OL Poisson's Ratio is 0.2, but no effect of LS Resilient Modulus is observed when OL Poisson's Ratio is 0.1.

Q.3 ANALYSIS OF WET-WARM BONDED CONCRETE OVERLAY

For the Wet-Warm region, models with OL Thickness, CRC Thickness, Curl/Warp, OL Coefficient of Contraction, and Strength-OL as main effects and all possible two-way interactions were explored. Table Q-5 contains the analysis of variance table for the model in Table Q-6, which shows the model is significant at $\alpha = 0.05$. There were originally 10 possible two-way interactions in addition to the 5 main effects. After removing the insignificant interactions from the model, a model in Table Q-6 was selected as an adequate model with respect to the terms included. All of the 8 interaction effects retained in the model were statistically significant at the level $\alpha = 0.05$.

Table Q-5. Analysis of Variance for the Wet-Warm Region.

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Model	18	88161.13	4897.84	61.24	<.0001
Error	29	2319.27	79.97		
C. Total	47	90480.40			

Table Q-6. Effect Tests for the Wet-Warm Region.

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Strength-OL	2	2	18793.54	117.50	<.0001
OL Thick	1	1	2347.10	29.35	<.0001
OL Coeff Contract	1	1	29054.67	363.30	<.0001
CRC Thick	1	1	6158.99	77.01	<.0001
Curl/Warp	1	1	6780.72	84.79	<.0001
Strength-OL×OL Thick	2	2	612.90	3.83	0.0334
Strength-OL×OL Coeff Contract	2	2	11150.92	69.72	<.0001
OL Thick×OL Coeff Contract	1	1	1357.00	16.97	0.0003
Strength-OL×CRC Thick	2	2	1459.71	9.13	0.0008
OL Coeff Contract×CRC Thick	1	1	3729.17	46.63	<.0001
Strength-OL×Curl/Warp	2	2	1993.66	12.46	0.0001
OL Coeff Contract×Curl/Warp	1	1	3835.55	47.96	<.0001
CRC Thick×Curl/Warp	1	1	887.19	11.093	0.0024

Since there are significant interaction effects (joint effects of two factors), the individual factor effects (main effects) can only be assessed conditional on each level of the other factor. Plots for the statistically significant interaction effects are presented in Figures Q-15 through Q-22. The conclusions drawn based on the interaction plots and the multiple comparison procedures are presented right after each interaction plot. The explanation of interaction plots and multiple comparison procedures were explained in the analysis for CRCP pavements. For space, the tables containing the results of multiple comparison procedures are not presented here.

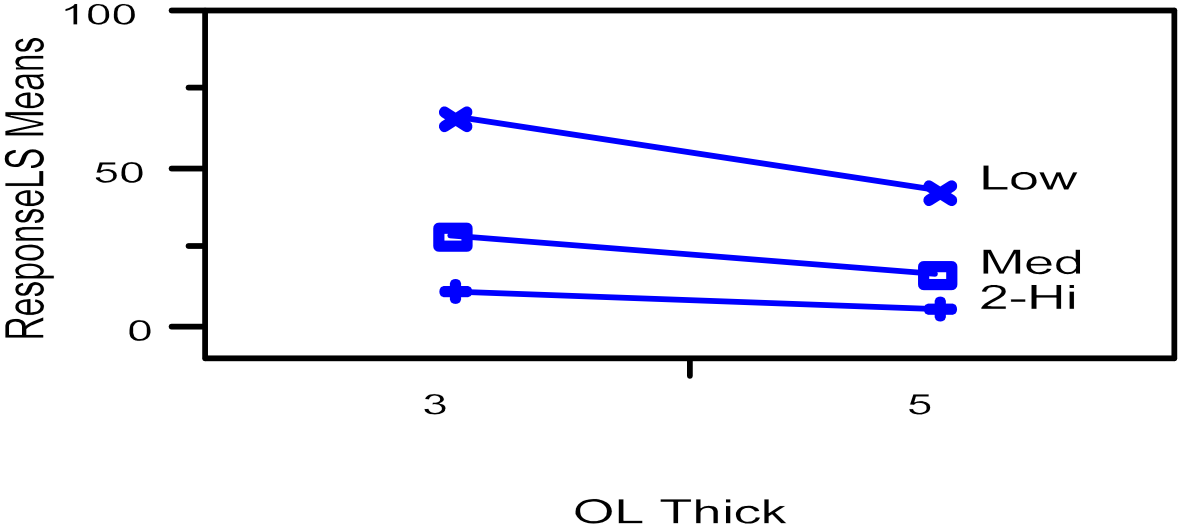

Figure Q-15. Interaction Plot for Strength-OL×OL Thick (Wet-Warm).

The effect of OL Thickness is different for each level of Strength-OL. For Strength-OL level Low, OL Thickness level 5 leads to less punchouts than OL Thickness level 3 does. For the other levels of Strength-OL, Med and 2-Hi, however, there is no effect of OL Thickness on punchouts.

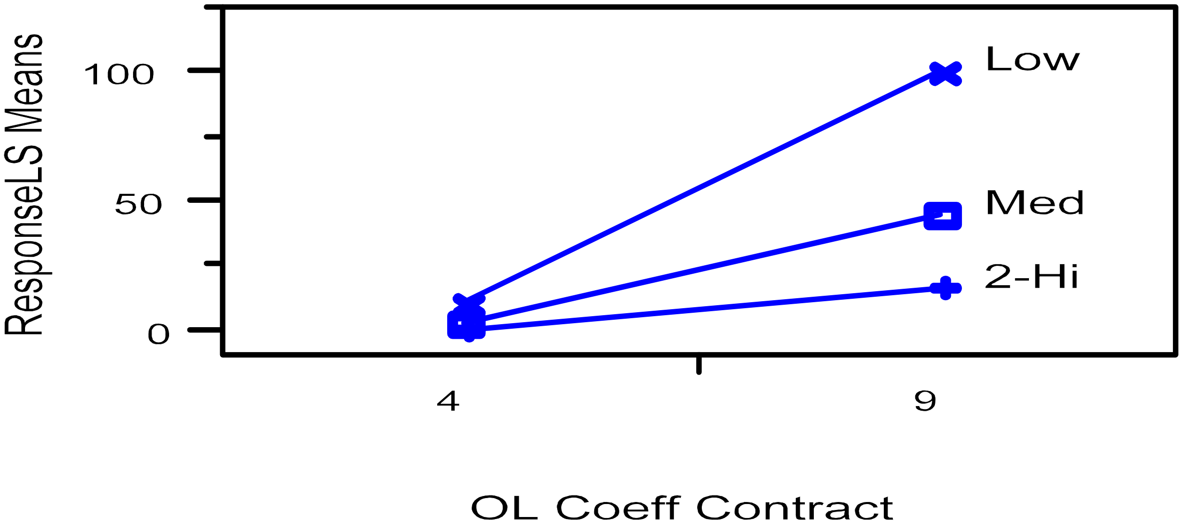

Figure Q-16. Interaction Plot for Strength-OL×OL Coeff Contract (Wet-Warm).

Strength-OL matters when OL Coefficient of Contraction is 9, i.e., Strength-OL Low leads to the most punchouts and Strength-OL 2-Hi leads to the least punchouts. However, when OL Coefficient of Contraction is 4, there is no difference in the mean punchouts for the three different levels of Strength-OL. In general, OL Coefficient of Contraction level 9 leads to more punchouts than OL Coefficient of Contraction level 4 regardless of the levels of Strength-OL. However, the magnitude of increase in punchouts when OL Coefficient of Contraction changes from 4 to 9 is different for each level of Strength-OL.

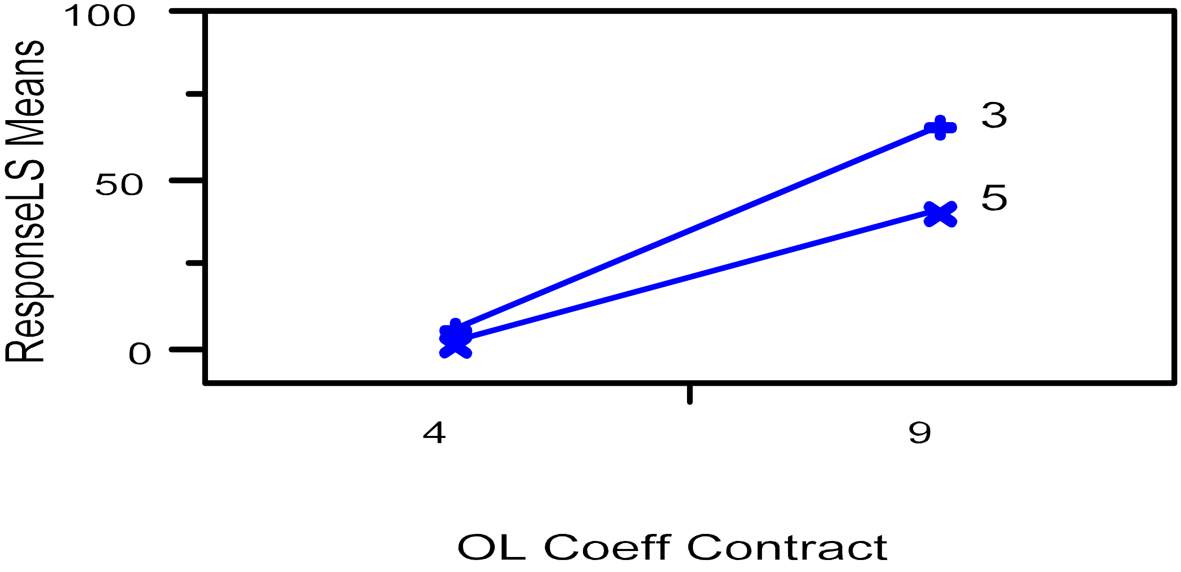

Figure Q-17. Interaction Plot for OL Thick×OL Coeff Contract (Wet-Warm).

OL Thickness matters when OL Coefficient of Contraction is 9, i.e., OL Thickness 3 leads to more punchouts than OL Thickness 5 does. However, when OL Coefficient of Contraction is 4, there is no difference in the mean punchouts for the two levels of OL Thickness.

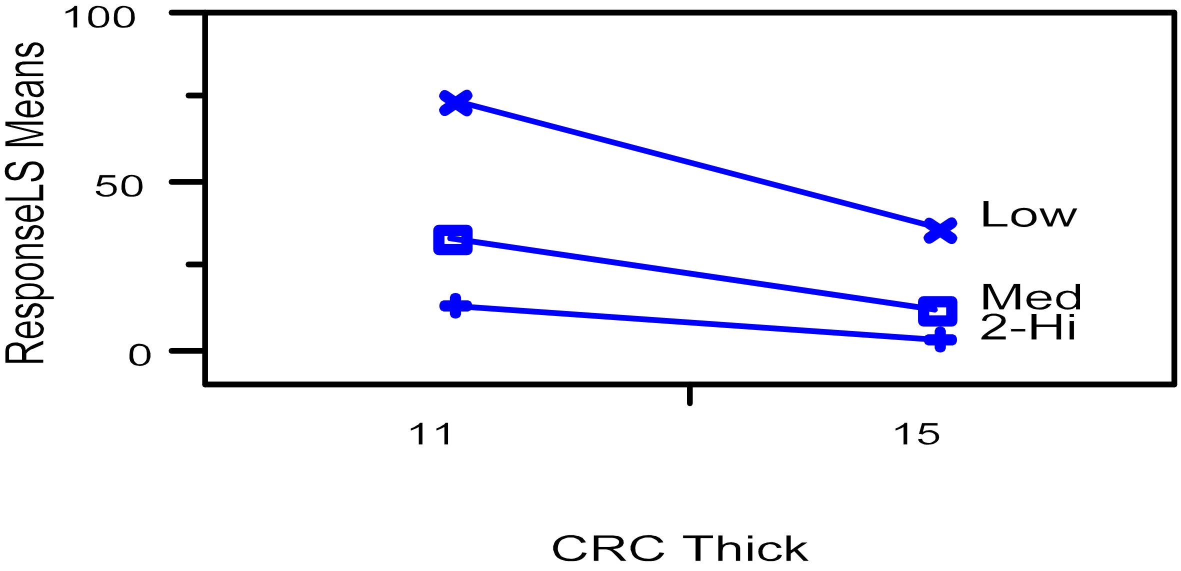

Figure Q-18. Interaction Plot for Strength-OL×CRC Thick (Wet-Warm).

The effect of CRC Thickness is different for each level of Strength-OL. For Strength-OL levels Low and Med, higher CRC Thickness leads to less punchout. However, for Strength-OL level 2-Hi, CRC Thickness does not matter, i.e., there is no significant difference in punchouts when CRC Thickness changes from 11 to 15.

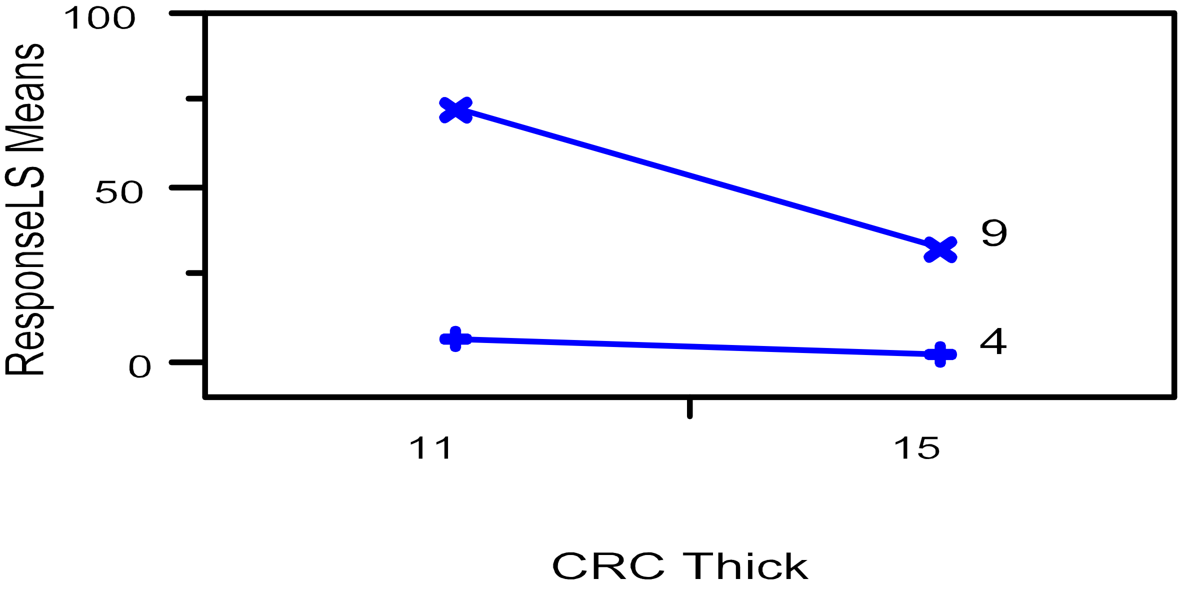

Figure Q-19. Interaction Plot for OL Coeff Contract×CRC Thick (Wet-Warm).

The effect of CRC Thickness is different for each level of OL Coefficient of Contraction. For OL Coefficient of Contraction level 9, higher CRC Thickness leads to less punchout. However, for OL Coefficient of Contraction level 4, CRC Thickness does not matter, i.e., there is no significant difference in punchouts when CRC Thickness changes from 11 to 15.

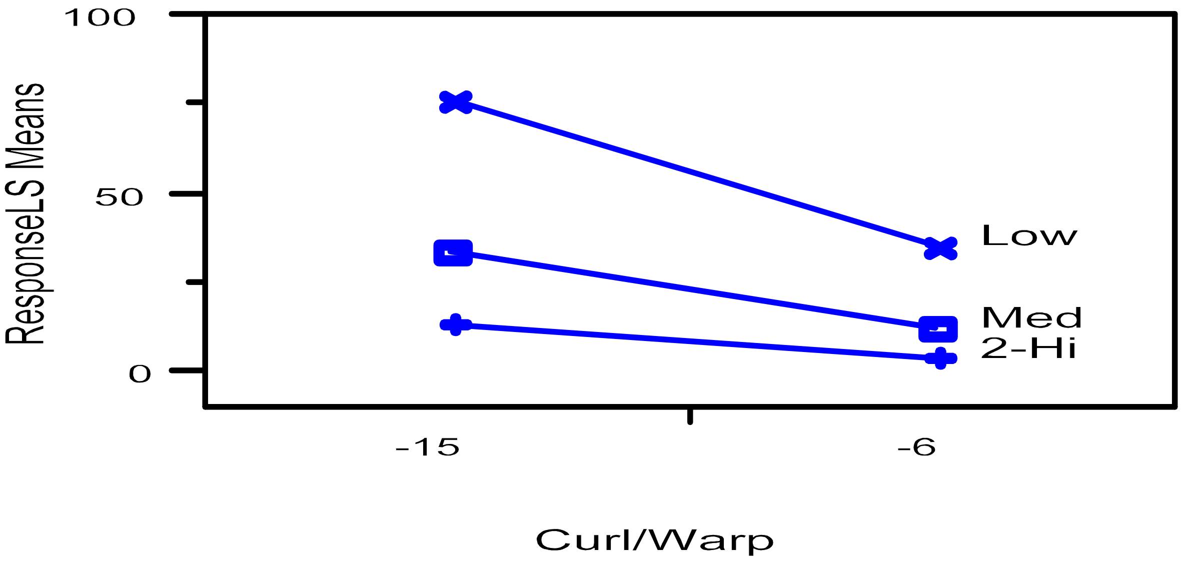

Figure Q-20. Interaction Plot for Strength-OL×Curl/Warp (Wet-Warm).

The effect of Curl/Warp is different for each level of Strength-OL. When Strength-OL is Low or Med, Curl/Warp −6 leads to less punchouts than Curl/Warp −15. There is, however, no significant difference in punchouts whether Curl/Warp is −15 or −6 when Strength-OL is 2-Hi.

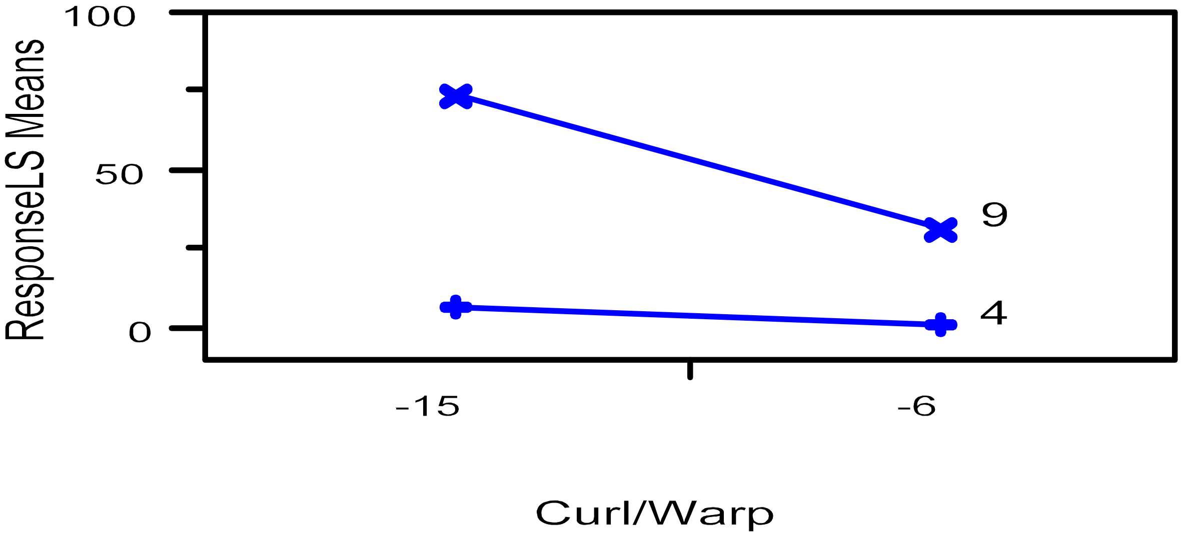

Figure Q-21. Interaction Plot for OL Coeff Contract×Curl/Warp (Wet-Warm).

In general, higher OL Coefficient of Contraction leads to more punchouts although the magnitude of increase in punchouts (when OL Coefficient of Contraction changes from 4 to 9) is different for each level of Curl/Warp. The effect of Curl/Warp is also different for each level of OL Coefficient of Contraction. Curl/Warp −6 leads to less punchouts than Curl/Warp −15 when OL Coefficient of Contraction is 9. There is no significant difference in punchouts whether Curl/Warp is −15 or −6 when OL Coefficient of Contraction is 4.

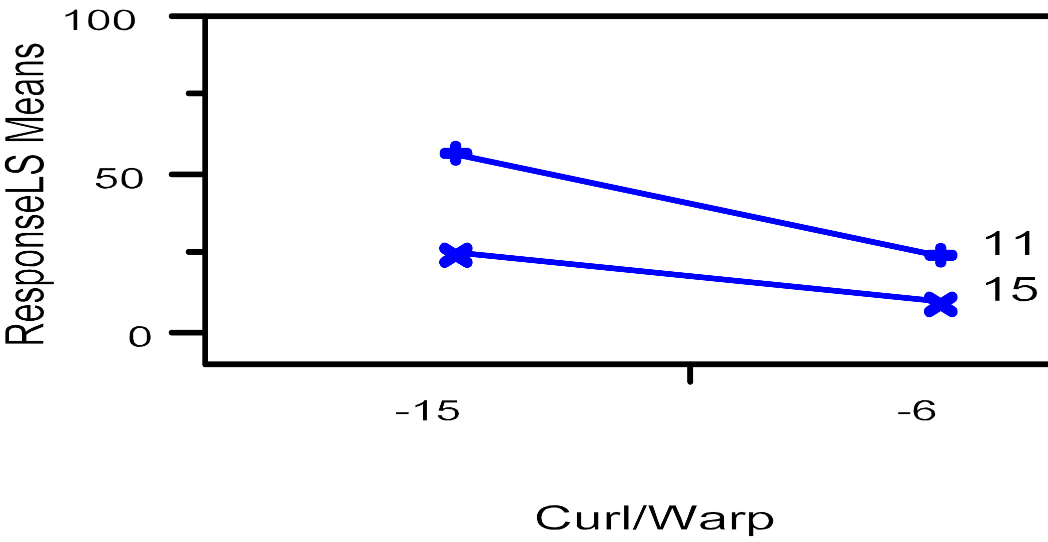

Figure Q-22. Interaction Plot for CRC Thick×Curl/Warp (Wet-Warm).

In general, punchouts decreases when CRC Thickness changes from 11 to 15 and/or when Curl/Warp changes from −15 to −6. The magnitude of decrease (factor effect) is, however, different for each level of the other factor. The effect of Curl/Warp is bigger for CRC Thickness level 11 than for CRC Thickness level 15. Likewise, the effect of CRC Thickness is bigger for Curl/Warp level −15 than for Curl/Warp level −6.