Guide For Mechanistic Empirical Design

This study developed traffic inputs for use with the Guide for the Mechanistic-Empirical Design of New & Rehabilitated Pavement Structures (MEPDG) in Virginia and sought to determine if the predicted distresses showed differences between site-specific and default traffic inputs for flexible and rigid pavements. The axle-load spectra, monthly adjustment factors, vehicle class distribution factors, and number of axles per truck inputs were considered. The predicted distresses based on site-specific traffic inputs from eight interstate and seven primary route weigh-in-motion sites in Virginia were compared to predicted distresses using MEPDG default traffic inputs. These comparisons were performed by use of a normalized difference statistic for each site-specific traffic input and the coefficient of variation for each pavement distress model. In addition, the practical significance for flexible pavements was considered from the difference in the predicted time to failure between site-specific and default traffic inputs. The analysis showed that the effect of the site-specific traffic inputs was generally not statistically significant when the uncertainty of the distress models was considered. However, the site-specific axle-load spectra and vehicle class distribution inputs showed a statistically significant effect on certain predicted distresses for flexible and rigid pavements, respectively. The study recommends that site-specific axle-load spectra data be considered for analysis of flexible pavements. Alternatively, summary (statewide average) axle-load spectra data for analysis of interstate and primary flexible pavements should be considered preferentially over default axle-load spectra. Site-specific vehicle class distribution factors should be considered for analysis of rigid pavements on the interstate system. Alternatively, summary (statewide average) vehicle class distribution factors for analysis of interstate rigid pavements should be considered preferentially over default vehicle class distribution data. Default traffic data are recommended for analysis of primary rigid pavements. This study also recommends that a local calibration process be completed to determine if the predictive models accurately predict the conditions found on Virginia's roadways. If the predictive models are modified, the results may impact the recommendations resulting from this study. The implementation of the recommendations of this study and the use of the MEPDG in general will provide the Virginia Department of Transportation with a more advanced means of designing and analyzing pavements. This should result in optimal designs that are more efficient in terms of initial construction and future maintenance costs.

This guide provides guidance to calibrate the Mechanistic-Empirical Pavement Design Guide (MEPDG) software to local conditions, policies, and materials. It provides the highway community with a state-of-the-practice tool for the design of new and rehabilitated pavement structures, based on mechanistic-empirical (M-E) principles. The design procedure calculates pavement responses (stresses, strains, and deflections) and uses those responses to compute incremental damage over time. The procedure empirically relates the cumulative damage to observed pavement distresses.

Abstract: The new Mechanistic-Empirical Pavement Design Guide (MEPDG) provides a state- of-the-art and practice pavement design procedure that eradicates the AASHTO 1993 empirical design procedure deficiencies. Huge advancements with respect to traffic input, material characterization and environmental impact are incorporated in the MEPDG. The AASHTO 1993 design procedure is based on empirical equations derived from the AASHO Road Test conducted in the late 1950's in a test track in Ottawa, Illinois. The test provided very useful information for the design of pavement at that time. However, with the present advancement in materials and dramatic increase in traffic volumes, this empirical design procedure started to show massive drawbacks. The MEPDG is a more comprehensive design procedure that incorporates sophisticated models for pavement response calculation, material properties variations with respect to environmental conditions and pavement performance predictions. The mechanistic part of the design procedure is the pavement response calculation and the empirical part of the method is the pavement performance prediction. Incorporating these models allows the MEPDG of producing pavement design sections that are cost-effective and perform better than those designed using the AASHTO 1993 design procedure for a given life span. With the initial introduction of the MEPDG in 2004, almost every State Highway Agency (SHA) in the United States and several road authorities around the world exerted efforts to understand and plan to implement the MEPDG according to their own local conditions. It was hence found necessary to explore the new design procedure according to Egyptian local conditions. The objectives of the research is to prepare a body of accurate and readily usable environmental data for Egypt for MEPDG input, compare the effectiveness of both design methods and assess the sensitivity of MEPDG predicted performance with respect to variations in inputs. Weather data files for major Egyptian cities were extracted from available data sources and prepared for direct input in the MEPDG. The preparation of data was done using a computer application especially developed in this research program to comprehensively and rationally complete this task. A comparative study was then done between the two design methods. Five pavement sections were designed using the AASHTO 1993 design procedure and then evaluated using the MEPDG for three traffic levels. These five sections were chosen to best represent the majority of Egypt. A sensitivity analysis was then conducted to investigate the predicted behavior of fatigue cracking and rutting with respect to variations in environmental conditions, traffic levels, AC layer thickness and properties, granular base (GB) layer thickness and subgrade strength. Comparing both design methods revealed that pavements designed under the AASHTO 1993 do not perform equally at the end of their design life. Terminal Present Serviceability Index (PSI) values are different for different traffic levels and locations. Predicted fatigue cracking and rutting showed a similar trend to terminal PSI values. The AASHTO 1993 was also found to over-estimate pavement layers thicknesses. Predicted fatigue cracking showed high sensitivity to design inputs under the scope of the study. Environmental conditions and traffic loading were also found to be the most influential input parameters on the selected pavement performance indices. Unexpected results for predicted rutting lead to further investigation and MEDPG rutting prediction model was evaluated with respect to an Egyptian rutting prediction model. Rutting prediction model adopted by MEPDG produced lower values for permanent strain compare to the Egyptian rutting model and further calibration for the MEPDG rutting prediction model was found necessary.

Introduction -- Mechanistic-Empirical Pavement Design Guide and AASHTOWare Pavement ME Design (TM) Software Overview -- Survey of Agency Pavement Design Practices -- Common Elements of Agency Implementation Plans -- Case Examples of Agency Implementation -- Conclusions.

The Wyoming Department of Transportation (WYDOT) has been working to fully implement MEPDG as their pavement design guide. To facilitate this implementation, many research works have been completed. Similarly, this thesis was completed to evaluate the relationships between subgrade resilient modulus (Mr) and the dynamic cone penetration (DCP) and the standard penetration test (SPT) results, select three best subgrade Mr predictive models based on both Mr and distress estimations, determine the sensitivity of the pavement design parameters on pavement distresses in Wyoming, and facilitate implementation of the MEPDG in the state of Wyoming. Two resilient modulus (Mr) predictive models were developed from the dynamic cone penetration (DCP) and the standard penetration test (SPT) results. To enhance the prediction of pavement performance distresses, 11 subgrade Mr predictive models were evaluated and three best models were identified and selected. Sensitivity of pavement distresses to influential variables was assessed. All pavement distresses were found to be sensitive to asphalt concrete thickness, and most of the distresses were found to be non-sensitive to asphalt concrete (AC) grade, base thickness, and base Mr. Finally, pavement design comparisons were made between the WYDOT 2012 user design guide and the recommended design guide based on locally calibrated properties. The average overall cost per square yard of the pavement structure designed using the WYDOT 2012 user design guide was found to be 21% higher than that based on the recommended design guide.

The Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures (MEPDG) is an improved methodology for pavement design and the evaluation of paving materials. The Virginia Department of Transportation (VDOT) is expecting to transition to using the MEPDG methodology in the near future. The purpose of this research was to support this implementation effort. A catalog of mixture properties from 11 asphalt mixtures (3 surface mixtures, 4 intermediate mixtures, and 4 base mixtures) was compiled along with the associated asphalt binder properties to provide input values. The predicted fatigue and rutting distresses were used to evaluate the sensitivity of the MEPDG software to differences in the mixture properties and to assess the future needs for implementation of the MEPDG. Two pavement sections were modeled: one on a primary roadway and one on an interstate roadway. The MEPDG was used with the default calibration factors. Pavement distress data were compiled for the interstate and primary route corresponding to the modeled sections and were compared to the MEPDG-predicted distresses. Predicted distress quantities for fatigue cracking and rutting were compared to the calculated distress model predictive errors to determine if there were significant differences between material property input levels. There were differences between all rutting and fatigue predictions using Level 1, 2, and 3 asphalt material inputs, although not statistically significant. Various combinations of Level 3 inputs showed expected trends in rutting predictions when increased binder grades were used, but the differences were not statistically significant when the calibration model error was considered. Pavement condition data indicated that fatigue distress predictions were approximately comparable to the pavement condition data for the interstate pavement structure, but fatigue was over-predicted for the primary route structure. Fatigue model predictive errors were greater than the distress predictions for all predictions. Based on the findings of this study, further refinement or calibration of the predictive models is necessary before the benefits associated with their use can be realized. A local calibration process should be performed to provide calibration and verification of the predictive models so that they may accurately predict the conditions of Virginia roadways. Until then, implementation using Level 3 inputs is recommended. If the models are modified, additional evaluation will be necessary to determine if the other recommendations of this study are impacted. Further studies should be performed using Level 1 and Level 2 input properties of additional asphalt mixtures to validate the trends seen in the Level 3 input predictions and isolate the effects of binder grade changes on the predicted distresses. Further, additional asphalt mixture and binder properties should be collected to populate fully a catalog for VDOT's future implementation use. The implementation of these recommendations and use of the MEPDG are expected to provide VDOT with a more efficient and effective means for pavement design and analysis. The use of optimal pavement designs will provide economic benefits in terms of initial construction and lifetime maintenance costs.

Each design input in the Mechanistic-Empirical Design Guide (MEPDG) required for the design of Jointed Plain Concrete Pavements (JPCPs) is introduced and discussed in this report. Best values for Pennsylvania conditions were established and recommended for each input by considering: 1-typical values suggested in the Pennsylvania Department of Transportation (PennDOT) publications and databases, 2-reccommendations in the MEPDG documentations based on nationwide data, and 3- laboratory/field tests performed in different tasks over the duration of three years for this study.

As AASH is expected to eventually adopt the MEPDG at its primary pavement design method, it is critical that the SDDOT become familiar with the MEPGD documentation and associated design software. The research conducted under this project was a first step toward achieving this goal.

"This digest summarizes key findings from NCHRP Project 1-40D, "Technical Assistance to NCHRP and NCHRP Project 1-40A: Versions 0.900 and 1.0 of the M-E Pavement Design Sofware," conducted by Applied Research Associates, Inc., and Arizona State University. The digest was prepared by Michael I. Darter ... [et al.]"--P. [1].

"This digest announces the availability of key products from NCHRP Project 1-37A, 'Development of the 2002 guide for the design of new and rehabilitated pavement structures: phase II, ' for evaluation"--Page 1 excerpt

Mechanistic-empirical Pavement Design GuideA Manual of PracticeAASHTOGuide for Mechanistic-empirical Design of New and Rehabilitated Pavement StructuresGuide for Mechanistic-empirical DesignOf New and Rehabilitated Pavement Structures : Final ReportGuide for the Local Calibration of the Mechanistic-empirical Pavement Design GuideAASHTO

In 2003, staff of the Virginia Transportation Research Council (now the Virginia Center for Transportation Innovation and Research) and the Virginia Department of Transportation (VDOT) developed a plan to collect traffic and truck-axle weight data to support the Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures, known as the Mechanistic-Empirical Pavement Design Guide (MEPDG). The purpose of this study was to review VDOT's traffic data plan for the MEPDG and revise it as needed. The review included an assessment of the data obtained from the VDOT and Virginia Department of Motor Vehicles weigh-in-motion (WIM) sites and the appropriateness of the truck weight groups in VDOT's traffic data plan. Information on truck travel patterns and characteristics was compiled. There is very little literature that provides specific information on the structure of a traffic data plan for the MEPDG. Guidance provided by the Federal Highway Administration allows for much flexibility in the development of such a plan. Most states are working to develop the plan, and such plans that are already in place vary considerably. The Corridors of Statewide

Significance in Virginia's statewide long-range multimodal transportation plan represent the routes where truck traffic is most prominent and therefore represent routes on which the VDOT plan should focus. The study recommends that VDOT continue with its current truck weight data plan for the MEPDG. With this plan, VDOT is positioned to implement the MEPDG from a truck data perspective, The WIM data comprise an important input to the MEPDG process that is expected to provide VDOT with more accurate pavement designs based on actual traffic loadings in Virginia.
Evaluation of LTPP climatic data for use in Mechanistic-Empirical Pavement Design Guide (MEPDG) calibration and other pavement analysis /
Validation of the new AASHTO Mechanistic-Empirical Pavement Design Guide's (MEPDG) nationally calibrated pavement distress and smoothness prediction models when applied under Utah conditions, and local calibration of the new hot-mix asphalt (HMA) pavement total rutting model, were recently completed as documented in UDOT Research Report No. UT-09.11 Implementation of the Mechanistic-Empirical Pavement Design Guide in Utah: Validation, Calibration, and Development of the UDOT MEPDG User's Guide, dated October 2009. This Draft User's Guide incorporates the findings of the model validation and local calibration report and provides information for use by UDOT's pavement design engineers during trial implementation of the MEPDG. This information includes an overview of the MEPDG procedure, information on installation of the software, guidelines for obtaining all needed inputs, guidance to perform pavement design using the software for new and rehabilitated HMA pavement and jointed plain concrete pavement (JPCP), and pavement design examples for new HMA pavement and new JPCP using the MEPDG software.
Characterization of pavement materials in the three hierarchical design levels of the proposed mechanistic-empirical pavement design (MEPD) guide involves application of the dynamic modulus technique for asphalt concrete and the resilient modulus for unbound materials. This approach, if adequately implemented, is expected to improve the road design processes. The advance design level recommends using actual laboratory test data of the dynamic and resilient modulus determined under simulated environmental and traffic loading conditions. To circumvent the need for conducting the mechanical test in lower design levels, predictive equations and correlations established with physical properties are used to estimate the mechanistic properties needed as input to the design software. This paper examines the simplifications incorporated in the model using results of dynamic and resilient modulus tests performed at the National Research Council Canada (NRC). For the covering abstract of this conference see ITRD number E211426.
The implementation of the Empirical-Mechanistic Pavement Design Guide (MEPDG) method for flexible and rigid pavements requires numerous input parameters. Most of these parameters can be easily determined while some require best estimates that are usually extracted from available literature. This thesis identifies the most critical input parameters in terms of their effects on the damage of pavements and their influence on the determination of the number of corrective maintenance cycles to be performed during the design life of pavements. It was found that for flexible pavement, change in the average monthly temperature by as little as results in large differences in the number of corrective maintenance cycles. Also, consistently with simple mechanics concepts, pavements on stiffer foundations performed better under the load and hence, required fewer number of the corrective maintenance cycles than those founded on more flexible soils. Also, variations in truck weights affected the outcome in terms of the estimated number of corrective maintenance cycles for flexible pavement. Hence, better estimates of the number of corrective maintenance cycles can be obtained when the analysis was based on larger numbers of truck samples. On the contrary, no significant difference in the final estimation of the number of corrective maintenance cycles was found for rigid pavements even when the average monthly temperatures were increased or decreased by as much as . Moreover, no major difference was observed when a larger sample of trucks was used as input for the analysis. Similarly, change in ambient temperature which is directly related to the differential temperature on the top and the bottom of the slab that may lead to the curling of the slab and faulting, was found not to be critical. Similar to the results obtained for flexible pavements, rigid pavement with stiffer foundation properties performed better in terms of the number of corrective maintenance cycles as they required fewer corrective maintenance cycles.
This research developed design tables of new flexible pavement structures for New York State Department of Transportation based on the Mechanistic Empirical Design Guide (MEPDG). The design tables were developed using the MEPDG software for Regions 1, 3, and 7 for Upstate part of New York State and for Regions 8, 10, and 11 for the Downstate part of New York State. The MEPDG software was used to run design cases for combinations of: climate conditions, traffic volume, subgrade soil stiffness (Mr) and pavement structures. The conditions that the MEPDG was used to run were: the road structures classified as Principal Arterial Interstate, design 95%reliability level, 15 and 20 year analysis period. Weight in Motion (WIM) data of Region 7 were used for Region 1 and 2, also WIM data of Region 8 were used for Region 10 and 11. Climatic data specifically for each region were used. The NYSDOT's Comprehensive Pavement Design Manual (CPDM) was initially used to obtain pavement design solutions for Region 7 and 8. The granular subbase materials and thicknesses recommended by CPDM were used but only the asphalt layer thicknesses was varied to include several values higher and lower than the thickness recommended by CPDM. The thickness of asphalt binder and surface layers were kept constant. Only the thickness of the base layer was changed. For each design combination, the design case with thinnest asphalt layer for which the predicted distress was less the performance criteria was selected as the design solution. The design solutions for Regions 7 and 8 were assembled in design tables. The examination of the design tables proved that, in general, Region 7 requires thicker pavement structures than Region 8 for same Annual Average Daily Truck Traffic (AADTT) and Resilient Modulus. In the second phase, the MEPDG was used to run for Region 1, 3, 10, 11. The design solutions were tabulated first to produce the design tables for each design case. Since it was expected that the climate changing has no effects on the design solutions for the regions which belong to the same New York State part, the design tables of Region 7 were compared with the design tables of Regions 1 and 3. In addition, the design tables of Region 8 were compared with those obtained for Regions 10 and 11. The comparisons proved that the change in location within the same part of New York State affects the design solution for the same combination of subgrade soil stiffness and truck traffic volume. In the third phase, the design tables for 80% design reliability were produced for each selected region. The design tables which were developed by this study provide flexibility to the designer to design the new flexible pavement structure. The designer should select the subgrade (Mr), AADTT, design life, and the design reliability; then, the design solution could be obtained directly from

the tables.

The Kansas Department of Transportation (KDOT) is moving toward the implementation of the new American Association of State Highway and Transportation Officials (AASHTO) Mechanistic-Empirical Pavement Design Guide (MEPDG) for pavement design. The MEPDG provides a rational pavement design framework based on mechanistic-empirical principles to characterize the effects of climate, traffic, and material properties on the pavement performance, as compared with the 1993 AASHTO Guide for Design of Pavement Structures. Before moving to the MEPDG, the nationally calibrated MEPDG distress prediction models need to be further validated and calibrated to the local condition. The objective of this research was to improve the accuracy of the MEPDG to predict the pavement performance in Kansas. This objective was achieved by evaluating the MEPDG-predicted performance of Kansas projects, as compared with the pavement performance data from the pavement management system (PMS), and calibrating the MEPDG models based on the pavement performance data. In this study, 28 flexible pavement projects and 32 rigid pavement projects with different material properties, traffic volumes, and climate conditions were strategically selected throughout Kansas. The AASHTO ME Design software (Version 1.3) was used in this study. The comparisons between the MEPDG-predicted pavement performance using the nationally calibrated models and the measured pavement performance indicated the need for the calibration of the MEPDG models to the Kansas conditions. For new flexible pavements, the MEPDG using the nationally calibrated models overestimated the rutting due to the overprediction of the deformation of the subgrade layer. Biases also existed between the predicted top-down cracking, thermal cracking, and International Roughness Index (IRI) and the measured data. The relationship between the measured and the predicted IRIs was more obvious than that for the cracking. Using the coefficients determined through local calibration in this study, the biases and the standard errors were minimized for all the models based on the statistical analysis. For new rigid pavements, very low mean joint faulting was measured in actual projects as compared with the default threshold of the MEPDG. The type of base course had a minor effect on the pavement performance. The traditional splitting data method was adopted in the process of local calibration. After the local calibration, the biases between the predicted pavement performance (mean joint faulting and IRI) and the measured pavement performance were minimized, and the standard errors were reduced.

"Highway agencies across the nation are moving towards implementation of the new AASHTO Mechanistic- Empirical Pavement Design Guide (MEPDG) for pavement design. The objective of this project was to implement the MEPDG into the daily operations of the Utah Department of Transportation (UDOT). The implementation of the MEPDG as a UDOT standard required modifications in some UDOT pavement design protocols (i.e., lab testing procedures, equipment, and protocols, traffic data reporting, software issues, design output interpretation, and others). A key requirement is validation of the MEPDG's nationally calibrated pavement distress and smoothness prediction models when applied under Utah conditions and performing local calibration if needed. This was accomplished using data from Long Term Pavement Performance (LTPP) projects located in Utah and UDOT pavement management system (PMS) pavement sections. The nationally calibrated MEPDG models were evaluated. With the exception of the new hot-mix asphalt (HMA) pavement total rutting model, all other models were found to be reasonable. The rutting model was locally calibrated to increase goodness of fit and remove significant bias. Due to the nature of the data used in model validation, it is recommended that further MEPDG model validation be accomplished in the future using a database that contains HMA pavement and jointed plain concrete pavement (JPCP) exhibiting moderate to severe deterioration. This report represents Phase II of the UDOT MEPDG implementation study and builds on the Phase I study report completed in 2005 for UDOT. The Draft User's Guide for UDOT Mechanistic-Empirical Pavement Design (UDOT Research Report No. UT-09.11a, dated October 2009) incorporates the findings of this report as inputs and pavement design guidelines for Utah for use by UDOT's pavement design engineers during trial implementation of the MEPDG"--Technical report documentation page.

This research evaluated the low temperature creep compliance and tensile strength properties of Wisconsin mixtures. Creep compliance and tensile strength data were collected for 16 Wisconsin mixtures representing commonly used aggregate sources and binder grades. Engineering and statistical analyses were performed on the data to provide recommendations for using measured mechanical properties in thermal cracking analyses with the Mechanistic-Empirical Pavement Design Guide (MEPDG), and to evaluate the thermal fracture resistance of Wisconsin mixtures.

The AASHTO Guide for Design of Pavement Structures is the primary document used by the state highway agencies to design new and rehabilitated highway pavements. Currently the Kansas Department of Transportation (KDOT) uses the 1993 edition of the AASHTO pavement design guide, based on empirical performance equations, for the design of Jointed Plain Concrete Pavements (JPCP). However, the newly released Mechanistic-Empirical Pavement Design Guide (MEPDG) provides methodologies for mechanistic-empirical pavement design while accounting for local materials, environmental conditions, and actual highway traffic load distribution by means of axle load spectra. The major objective of this study was to predict pavement distresses from the MEPDG design analysis for selected in-service JPCP projects in Kansas. Five roadway sections designed by KDOT and three long term pavement performance (LTPP) sections in Kansas were analyzed. Project-specific construction, materials, climatic, and traffic data were also generated in the study. Typical examples of axle load spectra calculations from the existing Weigh-in-Motion (WIM) data were provided. Vehicle class and hourly truck traffic distributions were also derived from Automatic Vehicle Classification (AVC) data provided by KDOT. The predicted output variables, IRI, percent slabs cracked, and faulting values, were compared with those obtained during annual pavement management system (PMS) condition survey done by KDOT. A sensitivity analysis was also performed to determine the sensitivity of the output variables due to variations in the key input parameters used in the design process. Finally, the interaction of selected significant factors through statistical analysis was identified to find the effect on current KDOT specifications for rigid pavement construction. The results showed that IRI was the most sensitive output. For most projects in this study, the predicted IRI was similar to the measured values. MEPDG analysis showed minimal or no faulting and was confirmed by visual observation. Only a few projects showed some cracking. It was also observed that the MEPDG outputs were very sensitive to some specific traffic, material, and construction input parameters such as, average daily truck traffic, truck percentages, dowel diameter, tied concrete shoulder, widened lane, slab thickness, coefficient of thermal expansion, compressive strength, base type, etc. Statistical analysis results showed that the current KDOT Percent Within Limits (PWL) specifications for concrete pavement construction are more sensitive to the concrete strength than to the slab thickness. Concrete slab thickness, strength, and truck traffic significantly influence the distresses predicted by MEPDG in most cases. The interactions among these factors are also almost always evident.