Montana Department of Transportation
serving you with pride

Montana Department of Transportation August 2007
RESEARCH PROGRAMS

Project Summary Report 8158
Authors: James S. Moulthrop, PE; Fugro Consultants, Inc.
Harold L. Von Quintus, PE; Applied Research Associates, Inc.

Mechanistic-Empirical Pavement Design Guide Flexible Pavement Performance Prediction Models for Montana

http://www.mdt.mt.gov/research/projects/pave/pave_model.shtml

Introduction

The objective of this research study was to develop performance characteristics of flexible pavements in Montana and to use them in the implementation of distress prediction models. Reliable distress prediction models will enable the Montana Department of Transportation (MDT) to use Mechanistic-Empirical (ME) based principles for flexible pavement design and to manage the Montana highway network. This study focused on using the Mechanistic-Empirical Pavement Design Guide (MEPDG) software (NCHRP Project 1-37A) to develop local calibration factors for Montana climate, structures, and materials for flexible pavements.

What we did

FWD Comparison Study

A comparison study was performed between the MDT and LTPP FWD equipment to identify any bias that might exist.

Materials Testing

Materials testing included materials sampling, baseline condition testing, and laboratory testing to define material properties and layer thickness at each test site (Figures 1 and 2). Laboratory testing included repeated load resilient modulus and volumetric properties of unbound materials, including maximum dry density and optimum moisture content. Strength and elastic modulus tests were conducted on cement stabilized base cores. HMA layers were tested for creep compliance, indirect tensile strength, and volumetrics.

Performance Monitoring

Performance monitoring documented time series data and included surveys taken at the same time of year for three of the five year project duration. Distress surveys were performed in June; Falling Weight Deflectometer (FWD) testing was performed in April-May and August; and pavement profile testing was conducted in August and October.

Calibration of MEPDG Performance Models

One of the primary purposes of this study was calibration refinement of the MEPDG distress transfer functions for flexible and semi-rigid pavements, and HMA overlays constructed in Montana. Semi-rigid pavements were not originally calibrated by NCHRP; MDT is upgrading their work for future designs. The calibration refinement procedure used was similar to that used in NCHRP Project 1-40B.

All assumptions made and used in formulating the MEPDG procedure were accepted for use in Montana. Global calibration coefficients included in Version 0.9 of the MEPDG were used initially to predict the distresses and smoothness of the Montana calibration refinement test sections to determine any prediction model bias. These runs were considered a part of the validation process, similar to the process used under NCHRP Projects 9-30 and 1-40B.

An initial performance prediction exercise was conducted for the 10 Non-LTPP experimental sites (Figure 2). Material test data together with historical traffic and climatic data were used to predict rutting and fatigue cracking in the HMA layer and rutting in the unbound layers. Predicted distress was compared to

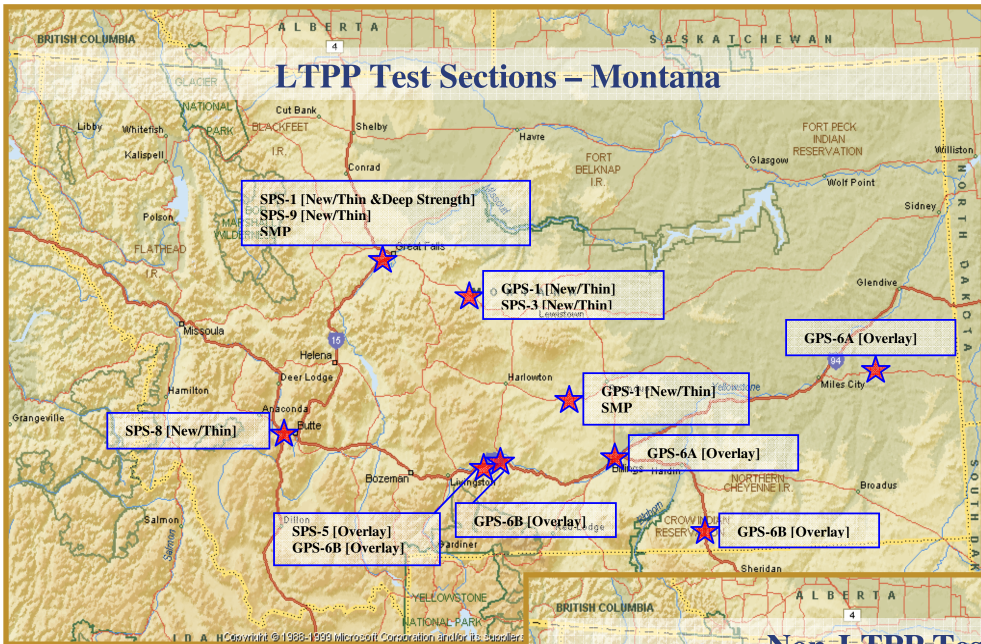

Figure 1. LTPP Test Sections in Montana.

the two distress surveys and rutting measurements available for these sites.

What we found

FWD Comparison Study

Comparisons in measured deflection and backcalculated moduli between the MDT and LTPP FWD equipment exhibited significant differences.

For the most part, LTPP equipment measured higher deflections for all sensors and drop heights compared to the MDT equipment. The bias was higher for Sensor 1 and decreased outward from the load (Sensor 1).

For backcalculated moduli, a clear bias between the two pieces of equipment was observed only for the modulus of the asphalt concrete (surface) layer.

The ratio E_{MDT}/E_{LTPP} for the asphalt concrete layer ranges from a value of 1.5 at 300,000 psi to 1.0 at 2,000,000 psi. A simple correlation was developed.

Materials Testing

Test results of binder, resilient modulus, and asphalt concrete mixtures are contained in the Final Report; asphalt concrete testing results included: Aggregate Gradation, Air Voids, Asphalt Content, Indirect Tension, Creep Compliance, and Resilient Modulus (indirect diametral).

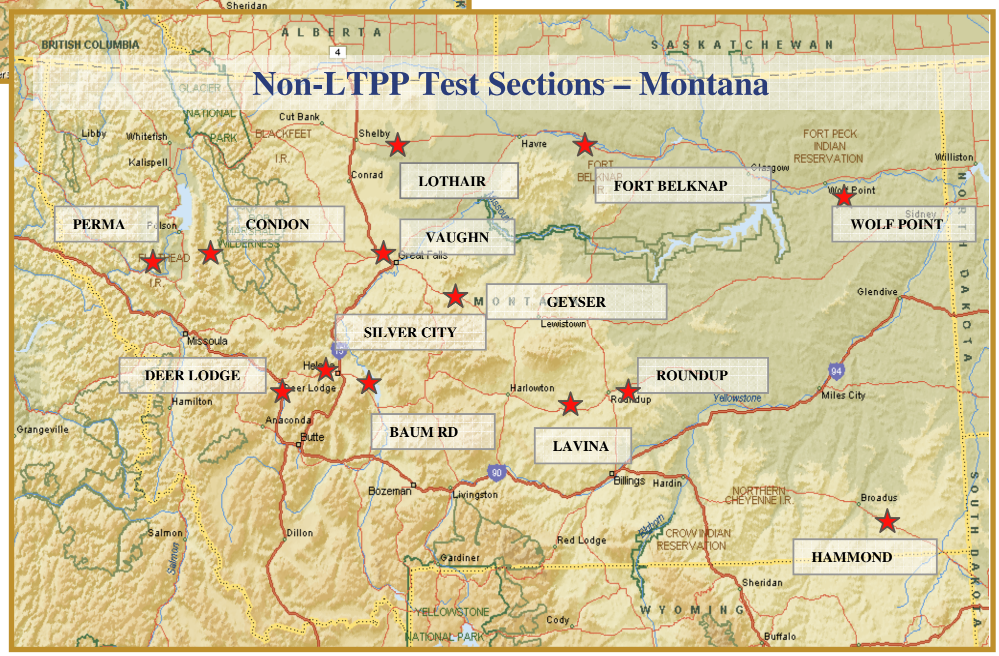

Figure 2. Non-LTPP Test Sections in Montana.

Calibration of MEPDG Performance Models

The calibration technique (the specific steps required to determine calibration coefficients) was demonstrated to MDT utilizing models similar to the MEPDG. A detailed discussion of the calibration algorithm accompanied by examples and step-by-step instructions is included in the Final Report.

FWD and laboratory resilient modulus values for unbound soils were different than FHWA recommendations. This was due to lower moisture in the unbound materials.

What the researchers recommend

Conversion of Backcalculated Modulus Values

For rehabilitation designs in the MEPDG, HMA damage modulus is determined from FWD backcalculated elastic modulus values. These need to be adjusted if the MDT JIL's device is used. In addition, the elastic modulus must be converted to laboratory equivalent Resilient Modulus, using factors tabulated in the report.

Rut Depth Prediction Model

The MEPDG over predicted total rut depth because significant rutting was predicted in unbound layers and embankment soils. Most thicker test sections located in Montana exhibit minimal rutting below the HMA layers based on field investigations from this project. Thus, a local adjustment factor for the unbound layers was determined.

Fatigue Cracking Prediction Model for Alligator or Bottom-Up Fatigue Cracking

The MEPDG fatigue cracking model was found to be reasonable. The standard error for the area fatigue cracking prediction model was relatively large, but reasonable for a distress that exhibits high variability. Variability in measured area fatigue cracking did significantly increase the standard error for this prediction model. It is recommended the bottom-up fatigue cracking (alligator or area cracking) model be used in Montana for pavement design.

Fatigue Cracking Prediction Model for Semi-Rigid Pavements

Two factors have a significant impact on the use of the MEPDG to design semi-rigid pavements in Montana. First, the fatigue cracking prediction model included in the MEPDG was never calibrated under NCHRP Projects 1-37A or 1-40D. Thus, test sections located in adjacent States, which performed more poorly than Montana sections, were used to determine local calibration adjustment factors. Secondly, a programming error exists in the MEPDG for cement-treated layers. The MEPDG was used to predict the fatigue cracking of this pavement design strategy by varying local calibration coefficients. These local coefficients were found to be mixture quality dependent. Mean values are recommended for use in designing semi-rigid pavement in Montana. However, it should be clearly understood those local calibration coefficients are heavily based on the test sections that were built in adjacent States, and will give slightly conservative results.

Fatigue Cracking Prediction Model for Longitudinal or Top-Down Fatigue Cracking

No consistent trend in the predictions could be identified to reduce bias and standard error, and improve accuracy of this prediction model. The top-down fatigue cracking model is not recommended for use in making design decisions in Montana until it is further refined based on work completed under NCHRP Project 1-42.

Thermal Cracking Prediction Model

A local calibration factor for predicting thermal cracking was developed. This factor was agency dependent for the test sections located in adjacent States. The MEPDG prediction model with the local calibration factor was found to be acceptable for predicting transverse cracks in HMA pavements and overlays in Montana. The standard error is relatively large, but similar to the standard error determined from updated calibration work completed under NCHRP Project 1-40D. Thus, the MEPDG and local adjustment factor are suggested for use in designing HMA mixtures.

Smoothness Prediction Model

The MEPDG prediction model for smoothness resulted from a regression analysis of hundreds of test sections included in the LTPP program, with reasonable error terms. This prediction model is not based on mechanistic principles so it can only be revised using regression-based procedures. Since there are too few test sections with higher levels of distress in Montana and adjacent States to accurately revise this regression equation, the MEPDG prediction equations are recommended for use in Montana.

Recommendations for Future Calibration Studies

The MEPDG distress transfer functions have been validated for use in Montana. Bottom-up (alligator) fatigue and thermal cracking, HMA rut depth, and the smoothness prediction models are believed to be adequate for use in Montana. It is recommended MDT move forward with using these distress prediction models in analyzing and designing flexible pavements and HMA overlays.

MEPDG Distress Prediction Models Requiring Future Updates

Models recommended for future refinement and updated calibration studies include: Semi-Rigid Pavement Fatigue Cracking, Rutting in the Unbound Layer, and Longitudinal Cracking – Surface Initiated Fatigue Cracks.

Activities and Schedule for Future Calibration Updates

Recommendations for future calibration refinement updates for fatigue cracking of semi-rigid pavements and rutting in the unbound materials include:

1. Continue to collect traffic, distress, and profile (smoothness and rut depth) measurements on the non-LTPP test sections. Condition surveys should be made annually to determine when cracking starts to occur. All data should be entered into the MDT MEPDG calibration database. Once calibration refinement has been scheduled, any additional distress and performance data should be extracted from the LTPP database for those sections located in Montana and in adjacent States and Canadian provinces, and entered into the MEPDG database.
2. It is recommended deflection basin data be measured along each non-LTPP test section after fatigue cracking exceeds about 5% on any four semi-rigid sections.
3. A calibration update should be scheduled after greater than 5% fatigue cracking is observed on about half of the semi-rigid pavements located in Montana and established within the MDT MEPDG calibration database.
4. Cores should be taken through load-related cracks to confirm the direction of propagation. Confirmation of the MEPDG prediction model and mixture adjustment factors should continue as the semi-rigid fatigue cracking prediction and longitudinal cracking models are updated.

For More Details . . .

The research is documented in Report FHWA/MT-07-008/8158, *Mechanistic Empirical Pavement Design Guide Flexible Pavement Performance Prediction Models in Montana*.

MDT Project Manager:
Sue Sillick, ssillick@mt.gov, 406-444-7693

Fugro Consultants, Inc. Project Manager:
James Moulthrop, jmoulthrop@fugro.com, 512-977-1800

To obtain copies of this report, contact Sue Sillick, MDT Research Programs, 2701 Prospect Avenue, PO Box 201001, Helena MT 59620-1001, ssillick@mt.gov, 406-444-7693.

MDT Implementation Status
August 2007

The MDT Design Team will adopt the recommendations of this report to provide more cost-effective pavement designs. The latest software version (1.000) of the MEPDG is in use at MDT and new designs using our existing method from AASHTO (DARWin, 1993) are being checked. Existing projects and the existing distresses are being compared to those predicted by the new Design Guide. Data from distress surveys, traffic, smoothness, rut depths, and FWD testing will continue to be collected on an annual or biennial schedule. Regional calibration factors, as provided by this study, will be added to the software for future design and project reviews. Finally, a calibration update will be performed when fatigue cracking on about half of the semi-rigid pavements exceeds 5%.

For more information contact Dan Hill at, dahill@mt.gov, 406-444-3424.

200 copies of this public document were produced at an estimated cost of $0.95 each, for a total cost of $189.00.
This includes $0.00 for postage and $189.00 for printing.