

MDOT's Implementation Plan for the Mechanistic-Empirical Pavement Design Guide (MEPDG)

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Outline

- Need for adoption of the new design guide
- MDOT's plan for implementation
- PMS data considerations
- Recognize support from within MDOT for adoption of the new guide

Need for New Design Guide

A Little History

- Current MDOT flexible pavement design method based on the results of the AASHO Road Test
- Ottawa, Illinois
- Constructed between August 1956 and September 1958
- Test traffic placed between October 1958 and November 1960

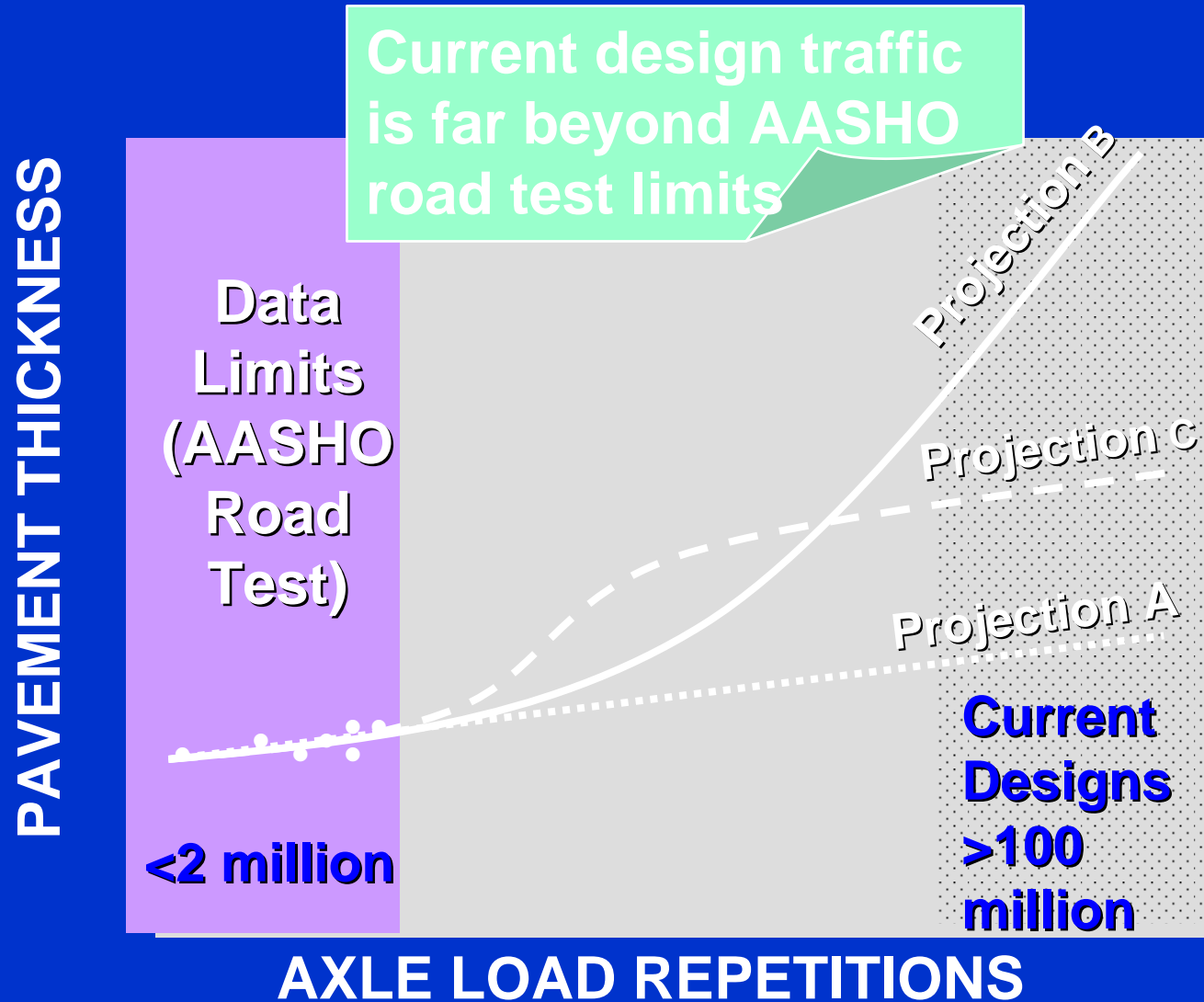
Summary of Design Guides Since AASHO Road Test

- AASHTO Interim Guide for Design of Pavement Structures – 1961, Revised 1972
- AASHTO Guide for Design of Pavement Structures – 1986, Revised 1993
- Current MDOT flexible pavement design procedure based on the 1972 Interim Guide
- Rigid pavements – 1998 Supplement to the AASHTO Guide for Design of Pavement Structures Part II Rigid Pavement Design and Rigid Pavement Joint Design

Differences Between 1972 Design Guide and New MEPDG

- One climate vs. multiple climates using EICM
- Flexible pavements – materials
 - 1972 guide characterized by structural layer coefficients (basically equivalency factors)
 - MEPDG fundamental engineering properties
- Traffic
 - 1972 guide – ESALS
 - MEPDG – Load Spectra (direct consideration of actual wheel loads, axle configurations and specific load intervals)

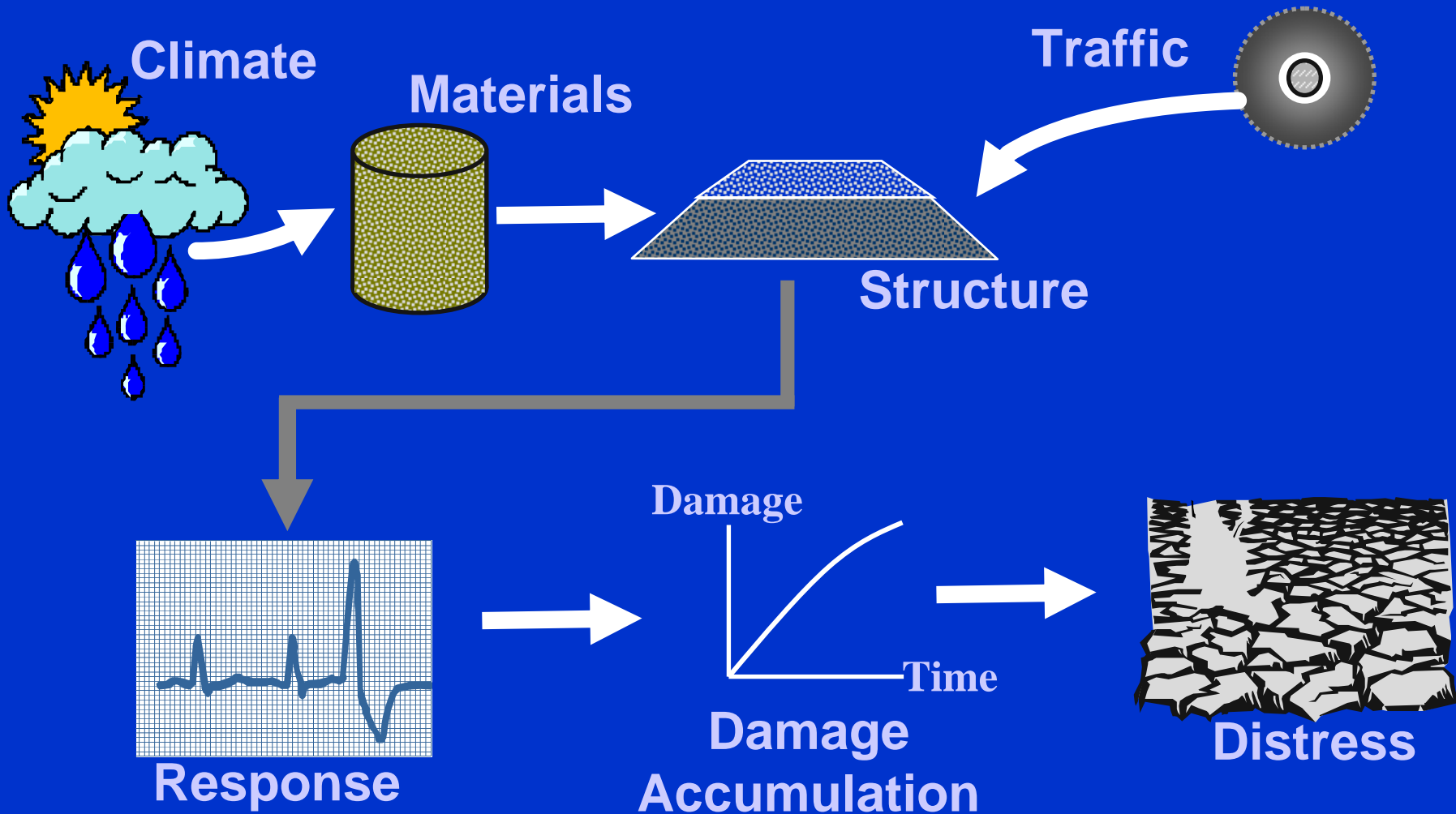
Project traffic beyond AASHO limits?



Changes in Design Traffic

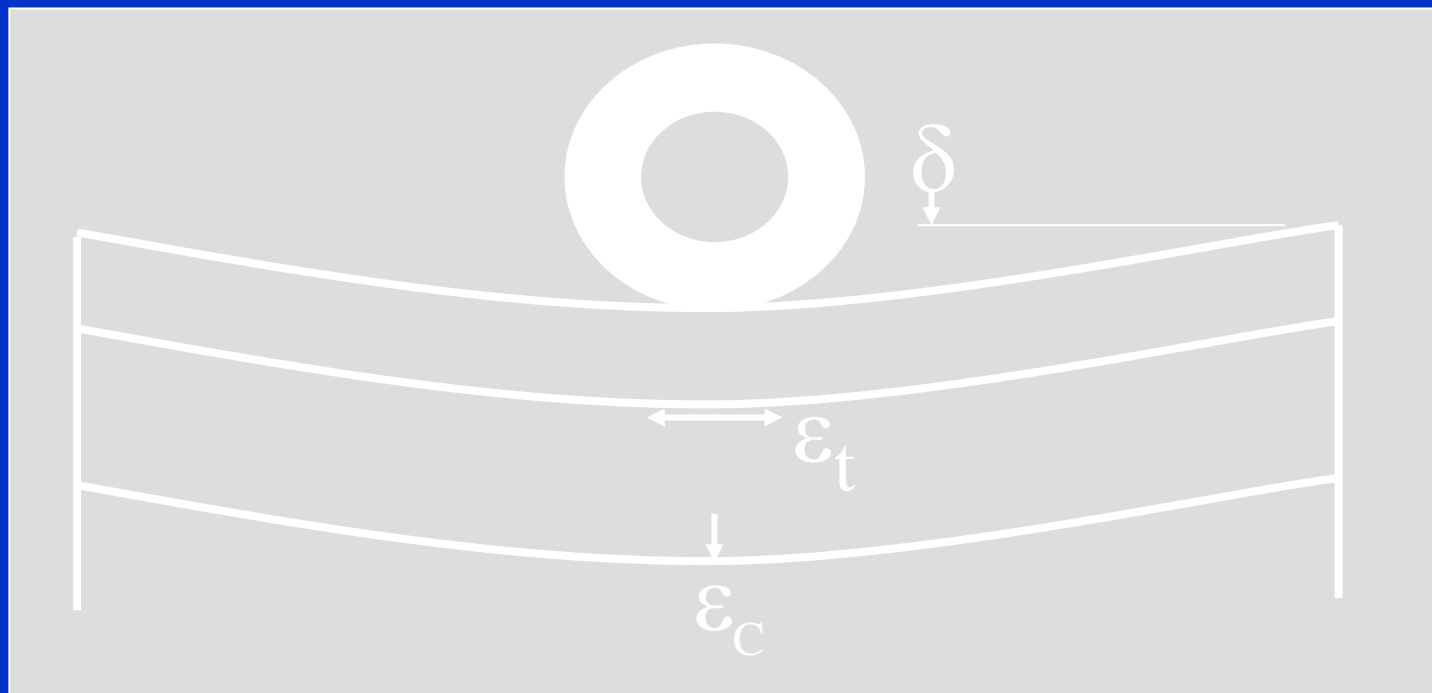
- Road Test Design Traffic – 8,000,000 ESALs
- Some current MDOT 20-year design traffic data:
 - MS 302 from US 51 to Swinnea RD - 21,762,000 ESALS
 - US 82 from Raceway RD to Leland – 16,504,000 ESALS
 - I-10 from Harrison County Line to SR 609 – 71,814,000 ESALS
 - I-55 from SR 24 to US 98W – 35,872,000 ESALS
- Extrapolation of traffic loadings from 2 to 9 times that of the Road Test

Mechanistic-Empirical Design



ME PDG Pavement Responses

- **Design of new and rehabilitated pavement structures based on engineering mechanics principles**



Flexible Pavement Distresses

Fatigue Cracking



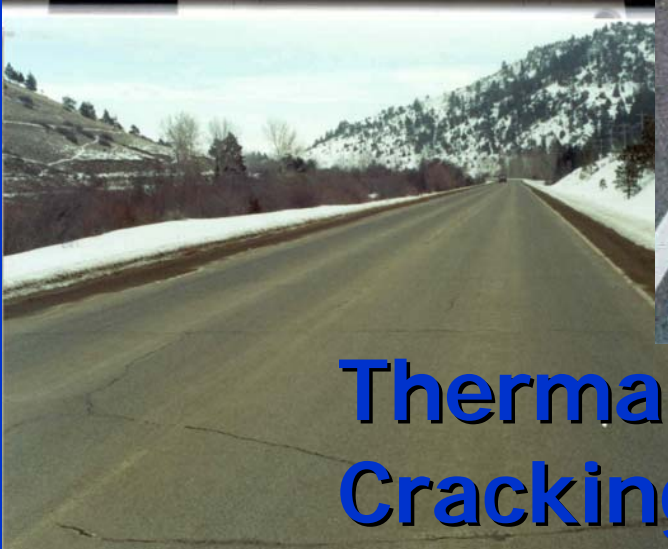
Longitudinal Cracking



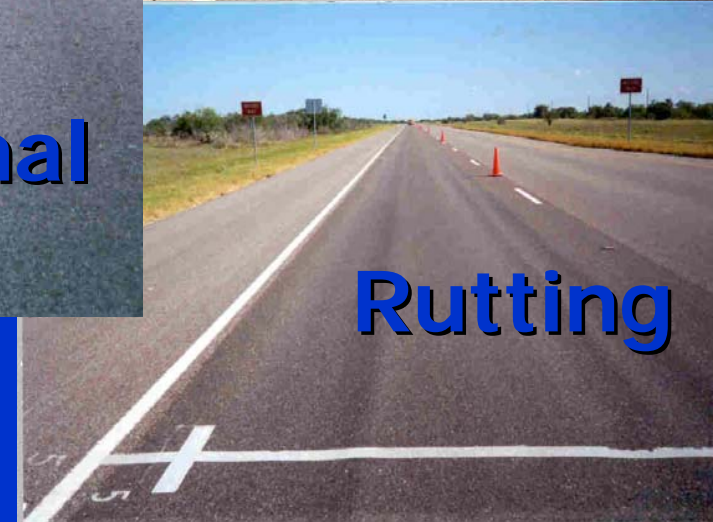
IRI



Thermal Cracking



Rutting



Pavement Responses and
Pavement Distresses Related Via
Transfer Functions

ME PDG Fatigue Cracking

$$N_f = 0.00432 \times C \times \beta_{f1} k_1 (\epsilon_t)^{-\beta_{f2} k_2} (E)^{-\beta_{f3} k_3}$$

$$C = 10^M$$

$$M = 4.84 \left((V_b (V_a + V_b)^{-1} - 0.69) \right)$$

Where:

- N_f : number of repetitions to fatigue cracking (predicted)
- ε_t : tensile strain at the critical location
- E : stiffness of the material
- k_1, k_2, k_3 : regression coefficients
- $\beta_{f1}, \beta_{f2}, \beta_{f3}$: calibration parameters
- V_a : air voids (%)
- V_b : effective binder content (%)

ME PDG generates

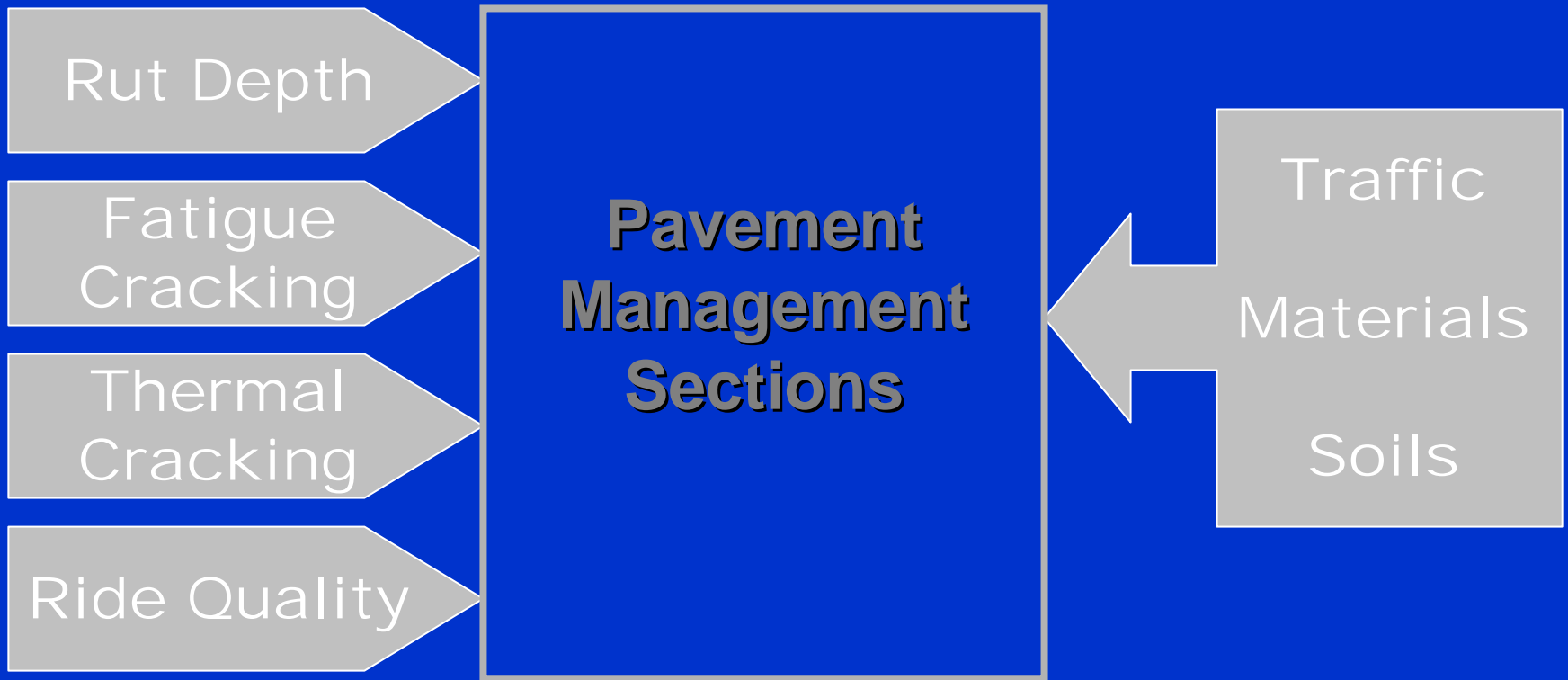
- N_f : number of repetitions to fatigue cracking (predicted)
- ε_t : tensile strain at the critical location

Sources of Data

- E : stiffness of the material
 - Dynamic modulus laboratory test
 - Estimated from models
- V_a : air voids (%)
 - Laboratory tests related to HMA mix design
 - Extraction tests on field cores
- V_b : effective binder content (%)
 - Laboratory tests related to HMA mix design
 - Extraction tests on field cores
- k_1, k_2, k_3 : regression coefficients obtained from laboratory testing of HMA mixes

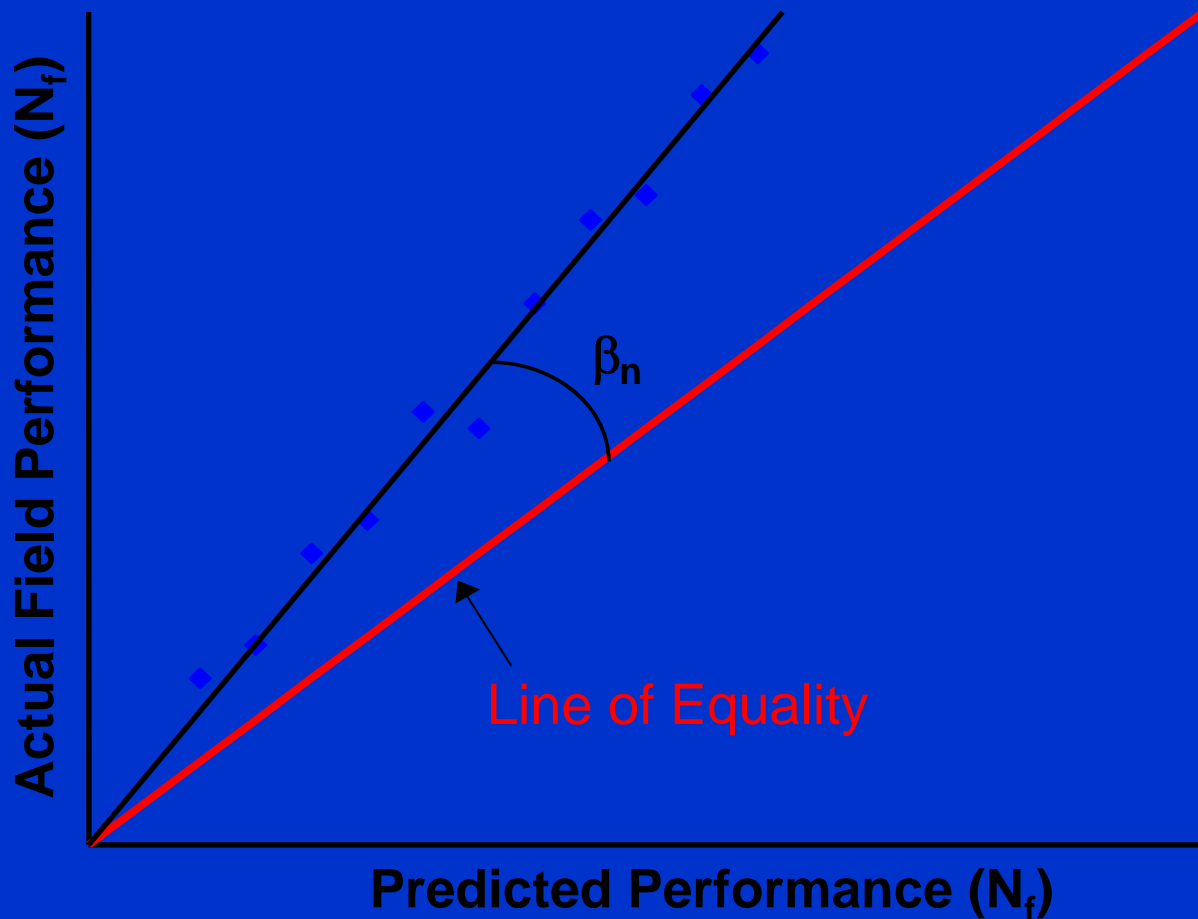
$\beta_{f1}, \beta_{f2}, \beta_{f3}$: calibration
parameters

PMS Data for Local Calibration

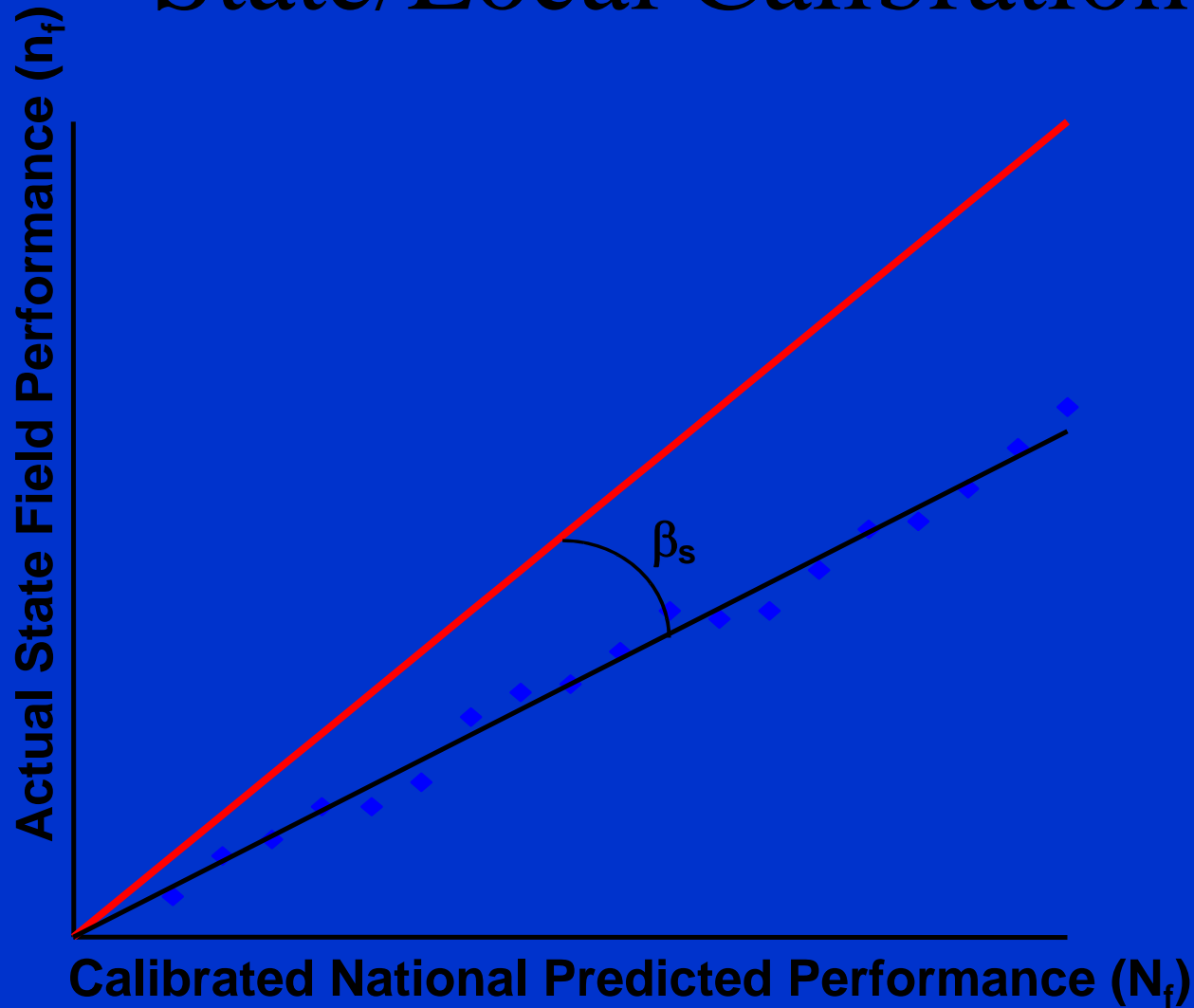


National Field Calibration

Purpose of field calibration
is to eliminate *bias*!



State/Local Calibration



MDOT's Plan for Implementation

Mississippi Two – Phase Implementation Approach

- Phase I - SS No. 163 “Develop Mississippi DOT’s Plan to Implement the 2002 Design Guide”
- Applied Research Associates (ARA)
- Logical choice due to firms’ involvement with:
 - NCHRP 1-37a – Initial MEPDG development
 - NCHRP 1-40 – Continued evolution of MEPDG
- Dr. Athar Saeed – PI, Vicksburg, MS office

Phase I Continued

- Consultant introduced MDOT staff to the requirements of the MEPDG
- Consultant became familiar with scope of pavement types and rehabilitations in MS
- Consultant prepare detailed plan for implementation – Phase II

Identification of Typical Pavements Used in Mississippi

- Product of SS # 163 - development of Factorial Experiment Design for Calibration and Validation of Distress Prediction Models
- Table that captures various combinations of pavement structural sections and materials used in Mississippi; i.e. for a given pavement:
- Type pavement – HMA or Concrete?

Experiment Design Continued

- If HMA:
 - Conventional?
 - Semi Rigid?
 - Deep Strength?
 - AC Overlay?
 - JPC?
 - CRCP?
- Polymer modified or neat binder?
- Superpave or Marshal mix design?
- Thickness of HMA – Low, medium, high?
- Chemically Stabilized or non stabilized subgrade?

Experiment Design Continued

- 44 potential different combinations just for HMA
- Each one requires calibration/validation!
- Agreement on definitions
 - What is a semi rigid pavement?
 - What is a deep strength pavement?
- Definitions are not the same between MDOT PMS and MEPDG
- MDOT queried the PMS data base, provided ARA with information, ARA divided pavements based on MEPDG definitions

Implementation - Phase II

- SS No. 170 “Implement the 2002 Design Guide for MDOT (Phase II)
- 12 funded support studies

Research Tasks for SS No. 170

- Applied Research Associates (ARA)
- Dr. Athar Saeed– PI, Vicksburg, MS office
- Review inputs required by the MEPDG
- Complete design guide software sensitivity analysis
- Assemble data for calibration and validation of performance models

Research Tasks for SS No. 170

Continued

- Calibration and validation of national performance models for Mississippi conditions/pavements
- Facilitate establishment of materials libraries
- Develop training materials and conduct training for MDOT personnel

Research Tasks for SS No. 170

Continued

- Subcontractor - Burns, Cooley, Dennis, Inc. (BCD)
- Performing M_r testing of typical MS subgrade soils
- Unbound aggregates
- Testing cementitious stabilized soils
 - Lime
 - LFA
 - Cement
- Test data included in materials library

12 Support Studies

- 2 in-house support studies
- 2 traffic
- 4 soils
- 2 HMA
- 2 Portland Cement Concrete

SS No. 171 “In-House Support to SS 170”

- Research Division engineer and technician salaries
- Huge amount of data to be provided by MDOT to ARA to support calibration/validation of models
- Need minimum 3 pavement analysis sections for each of the 44 potential combinations of pavement structure and material type
- 132 pavement analysis sections

SS # 171 Continued

- Each pavement analysis section includes at least 1-500 ft. sample – one per each mile of section length for collection of distress data
- One 500-ft sample selected from each analysis section for calibration/validation
- Selection criteria:
 - Located in tangent section
 - No intersections
 - No rail roads
 - No business sections
- Many sample sections do not fit the criteria

SS # 171 Continued

- For each selected 500-ft sample section:
 - Distress data from PMS
 - Materials data from Materials Division
 - Construction data from project diaries
- Visits to minimum 25 % of selected 500-ft samples to confirm PMS data, coring, fwd testing, trench studies, and traffic control

SS No. 165 “Traffic Load Spectra Development for the 2002 AASHTO Design Guide”

- Dr. Shane Buchanan – Previously with MSU
- Original study objective was to perform a state-wide characterization of traffic
- MDOT generated monthly W cards only contained traffic data from the last 2-4 days of each month instead of the entire month

SS No. 165 Continued

- W card issue corrected in January 2004.
- Raw binary code files still available to generate correct W card files, but traffic data would still be suspect because WIMs had not been calibrated on a regular basis
- Issue of WIM calibration also addressed
- Study limited to Mississippi LTPP traffic data

SS No. 165 Continued

- 2 of several conclusions:
- Characterize each road in State by Truck Traffic Classification (TTC) not functional classification
- Current flexible pavement design traffic inputs to obtain SN:
 - AADT
 - % Trucks
 - ESALS for 10 or 20 year design period
 - Flexible factor
- MEPDG design method requires data files to supply all of the inputs

SS # 188 Development of
Mississippi DOT'S Advanced
Traffic Loading Analysis System
(MS-ATLAS) to Support
MEPDG Implementation

Traffic Data Software

- 3 potential sources of software:
- MS ATLAS – ARA
- WIM Net – Fugro Consultants LP
- Traf Load – Developed under NCHRP 1-39

SS No. 188 Continued

- Basis for selection of software
- ATLAS used by ARA to provide national calibration of MEPDG distress models
- MDOT Planning Division personnel understand the collection of traffic data, but not issues related to designing pavements using load spectra
- ARA understands both traffic and design
- MS-ATLAS would require the least amount of beta testing by the Department's limited staff (both number and expertise)

Latest Issue With Traffic

- MDOT Planning Division is purchasing Transmetric R Traffic & WIM NET TR
- MDOT is first state to purchase
- Planning Division plan:
 - have raw traffic data processed, including QC/QA checks, by this new software
 - output of new software serve as input to MS-ATLAS
- Issue – MS-ATLAS programmed to accept raw traffic data, not output from new program

Materials Characterization

- Subgrade soils
- HMA
- Portland Cement Concrete

Methods to Evaluate Subgrade

- MEPDG requires resilient modulus, M_r , at optimum moisture content and maximum dry density
- Direct measurement – Level 1 input using laboratory test
- Estimate – level 2 input
 - Materials Library
 - Equations using soil index properties
 - In-situ testing

Laboratory Method

- Recommended by MEPDG
- Harmonized test procedure – Matt Witczak
- Considerations:
 - Time consuming
 - Expensive
 - Problems related to obtaining “representative” samples for testing

Materials Library

- BCD testing 30 typical Mississippi subgrade soils with Harmonized laboratory procedure
- Test sample preparation:
 - optimum moisture content
 - 95% Standard Proctor density
- Design M_r selection based on subgrade AASHTO soil classification, Group Index and volume change

SS No. 172 “Resilient Modulus Prediction Employing Soil Index Properties”

- Dr. K.P. George – University of MS
- Looked at various equations to predict soil M_r value from soil atterberg limits, gradation, moisture content, etc.
- Conclusion - LTPP equation yielded reasonable approximations

In-Situ

- Subgrade soil most variable component of pavement structure
- In-situ testing of subgrade may provide better estimate of subgrade M_r
 - Automated Dynamic Cone Penetrometer (ADCP)
 - Falling Weight Deflectometer (FWD)
 - Trailer Mounted typically used to test existing pavements
 - Portable FWD - PRIMA 100

SS No. 131 “Subgrade Characterization for Highway Pavement Design”

- ADCP correlated to M_r
 - TP-46 test protocol
 - Shelby tube samples
- Drs. K.P. George and Waheed Uddin –
University of MS
- Positive:
 - Pick up any layering in top 3 ft. of subgrade

SS # 131 Continued

- Concerns:
 - Marginal correlation equation for fine grain soils
 - More work needed on coarse grain soil equation
 - Issue is trying to correlate results from a punching or shearing type test
 - Relatively time consuming
 - Manual DCP operation is labor intensive
 - MDOT has 1 ADCP and more would be needed
 - ADCP equipment is expensive
 - Estimated \$25,000 per unit
 - Not including truck

SS No. 134 “In-House Support to SS No. 131”

- Research Division engineer and technician salaries
- 12 field test sections
- Obtain Shelby tube samples of soil for M_r testing

SS No. 153 “Falling Weight Deflectometer for Estimating Subgrade Moduli”

- Dr. K.P. George – University of MS
- Top of untreated in-place subgrade tested with trailer mounted FWD
 - Correlated to laboratory determined M_r (TP-46 protocol)
- Rapidly obtain numerous test results
- Good results
- Drawbacks – Need to correct field W% and density to lab opt. and density, 1 FWD

SS No. 179 “Portable FWD for In-Situ Subgrade Evaluation”

- Dr. K.P. George – University of MS
- Top of untreated in-place subgrade tested with PRIMA 100
 - Correlated to laboratory determined M_r (harmonized procedure)
- Rapidly obtain numerous test results
- Each of the 6 MDOT Districts could have one for total price much less than one FWD
- Need to correct field W% and density to lab opt. and density





SS No. 166 “Hot Mix Asphalt (HMA) Characterization for the 2002 AASHTO Design Guide”

- MSU study
 - Initiated by Dr. Shane Buchanan
 - Continued by Dr. Tom White
- MSU purchasing new test equipment
- Dynamic modulus, indirect tension
- Test results included in Materials Library and used for:
 - Calibration/validation of performance models
 - Subsequent flexible pavement designs

SS No 166 Continued

- 24 typical MDOT HMA mixes tested for dynamic modulus. Selection for testing:
- 3 different nominal maximum aggregate sizes 9.5mm, 12.5mm, 19.0mm
- 2 different types of aggregate
 - Gravel
 - Gravel/limestone blend
- 3 PG grades of binder
 - PG 67-22 (No polymer modifier)
 - PG 76-22, PG 82-22 (Polymer modifier)
- 3 levels for N_{design} 50, 65, 85 based on traffic

SS # 181 Structural Characterization of Asphalt Drainage Course Layers

- Drainage layer study
 - MDOT includes a 4” drainage layer in new 4-lane facilities
 - #57 crushed limestone, sandstone, or granite
 - 2.5 % PG67-22
- Purpose of study:
 - Evaluate design modulus and Poisson’s Ratio for new MEPDG

SS # 181 Continued

- Determine required test method
 - Mr?
 - Some shear strength test and then limit developed stresses in layer?
- Develop appropriate transfer function
 - Needed for MEPDG
 - Needed for overlay design using ELMOD 5
- Current MDOT pavement design policy does not include any structural benefit of drainage layer. Perhaps replace cementitious stabilized soil base course

SS No. 177 “Inputs of Portland Cement Concrete Parameters Needed for the Design of New and Rehabilitated Pavements in Mississippi”

- Dr. Ahmed Al-Ostaz – University of MS
- Laboratory testing 20 PCC mixes for potential rigid pavement construction

Test	Standard	Specimen size	Testing Frequency
Modulus of Rupture	ASTM C78	6" x 6" x 24" beams	7,14,28,90 days, 2 yrs.
Compressive Strength	ASTM C39	6" x 12" cylinders	7,14,28,90 days, 2 yrs.
Modulus of Elasticity	ASTM C469	6" x 12" cylinders	7,14,28,90 days, 2 yrs.
Tensile Strength	ASTM C496	6" x 12" cylinders	7,14,28,90 days, 2 yrs.
Coefficient of Thermal Expansion	AASHTO TP60	4" x 8" cylinders	28 days
Concrete Shrinkage	ASTM C157	1" x 1" x 11.24" bars	28 days
Unit Weight	ASTM C138	6" x 12" cylinders	7,14,28,90 days, 2 yrs.
Poisson's ratio	ASTM C469	6" x 12" cylinders	7,14,28,90 days, 2 yrs.

Aggregate	Source	Cement
Light Weight Chert (Gravel 2-54-2)	Northern part of Mississippi (B&B Concrete, Oxford-MS)	Cement Type I
		Cement Type I+ FA Class F
		Cement Type I+ FA Class C
		Cement Type I+ Slag
Dense Chert (Gravel 57)	Central part of Mississippi Breen Brothers Gravel Co., Inc	Cement Type I
		Cement Type I+ FA Class F
		Cement Type I+ FA Class C
		Cement Type I+ Slag
Small Maximum Size Chert (Gravel #69) TXI 6-L-20	Southern part of Mississippi (Gulf Concrete, LLC)	Cement Type I
		Cement Type I+ FA Class F
		Cement Type I+ FA Class C
		Cement Type I+ Slag
Alabama Lime Stone (A-8-L)	B&B Concrete, Oxford-MS	Cement Type I
		Cement Type I+ FA Class F
		Cement Type I+ FA Class C
		Cement Type I+ Slag
Kentucky Lime Stone (Lime Stone #57)	Kentucky (MMC)	Cement Type I
		Cement Type I+ FA Class F
		Cement Type I+ FA Class C
		Cement Type I+ Slag

Use of PCC Lab Results

- Calibration/Validation of MEPDG concrete performance models
- Included in materials library being developed in conjunction with SS # 170

FHWA Mobile Concrete Laboratory

- Workshop on Implementation of Rigid Pavement portion of MEPDG
 - University of Mississippi
 - August 2, 2005
- Utilized for interlaboratory comparison testing between the MCL and UM
 - AASHTO TP 60 Standard Test Method for the Coefficient of Thermal Expansion of Hydraulic Cement Concrete

SS No. 187 “Effect of Moisture Content on Thermal Coefficient of Expansion of Concrete”

- AASHTO TP 60 utilizes saturated samples
- In-service rigid pavements are not usually saturated
- SS NO. 187 evaluates:
 - CTE at varying levels of concrete moisture content for a given aggregate
 - Looks at this effect for different aggregates
 - Same mix designs used as for SS No. 177

Research Approach

- Perform CTE testing of specimens:
 - fully saturated
 - no moisture
- Perform sensitivity analyses with MEPDG software (ARA)
- If sensitivity is significant then test for CTE at intermediate levels of moisture content
- 3 different methods used to evaluate CTE:
 - AASHTO TP 60
 - Strain Gauging Technique
 - Danish Standard T1-B

PMS Data Considerations

Network vs. Project Level Data

- PMS reports average values of distress and IRI over entire analysis section
- MEPDG calibration/validation requires data extracted for a 500-ft sample section within a given analysis section
- Disconnect with referencing points on ground
 - Construction plans and material data referenced to stations
 - PMS data referenced via County/route/log mile
- Distress rater subjectivity for different survey years - block vs. alligator, level of severity, pavement condition improves?

2-Stage Implementation Strategy

- Via SS # 170 complete initial calibration/validation of MEPDG models using construction, materials and PMS data on existing pavements
- For new construction begin building data base of requisite information for a recalibration in possibly 10 years

2-Stage Strategy Continued

- Collect project-level distress data on 500-ft sample sections of new projects
- Use following criteria for data collection:
 - Collect data on a sunny clear day to obtain clear picture for distress analysis.
 - Collect data 1 hour after sunrise or no later than 1 hour before sunset.
 - Collect data every year at approximately the same time and/or temperature
 - Collect at speeds over 40 mph for IRI
 - Keep lenses clean

2-Stage Strategy Continued

- Data collection criteria continued:
 - Train raters well and use same raters every year for distress analysis (Thanks Cindy)
 - Use good quality control plan for data collection
 - Have good definition of distress types and severity levels

Support from within MDOT for adoption of the new guide

- Management
- Financial

9 Member Technical Advisory Committee

- Upper Management:
 - Richard Sheffield, P.E. – Assistant Chief Engineer Operations
 - David Foster, P.E. – Assistant Chief Engineer Preconstruction
 - Melinda McGrath, P.E. – Assistant Chief Engineer Operational Maintenance

9 Member Committee Continued

- Randy Battey, P.E. – State Research Engineer
- Keith Purvis, P.E. – Assistant Roadway Design Engineer
- Barry Boyd, P.E. – District One Materials Engineer
- Alan Cross, P.E. – District Five Materials Engineer
- Jeff Altman, P.E. – Traffic Analysis Manager, Planning Division
- William Barstis, P.E. – Pavement Research Engineer, Research Division

Summary of Budget Study Costs

- SS 163 Phase I \$ 14,715
- SS 170 Phase II \$807,163
- SS 171 Support \$200,000
- SS 165 Traffic \$ 40,000
- SS 188 MS-ATLAS \$174,997
- SS 172 M_r - Equations \$ 19,098
- SS 131 ADCP \$244,340
- SS 134 Support to 131 \$ 75,000

Summary of Costs Continued

Financial Support

- Financial support from three MDOT Central Office Divisions to fund SS No 170
 - Roadway Design Division
 - Materials Division
 - Research Division

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Research Reports

The research findings are published in reports. All publications are available for download in the PDF format, which is viewable using Adobe Acrobat Reader.

Thanks to:

- Athar Saeed
- Ahmed Al-Ostaz
- Randy Battey
- Cindy Drake
- James Watkins

QUESTIONS?