MEPDG Work Plan Task No. 7:

Existing Pavement Input Information for the Mechanistic-Empirical Pavement Design Guide

Final Report
February 2009

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16. Abstract

The objective of this study is to systematically evaluate the Iowa Department of Transportation's (DOT's) existing Pavement Management Information System (PMIS) with respect to the input information required for Mechanistic-Empirical Pavement Design Guide (MEPDG) rehabilitation analysis and design. To accomplish this objective, all of available PMIS data for interstate and primary roads in Iowa were retrieved from the Iowa DOT PMIS. The retrieved data were evaluated with respect to the input requirements and outputs for the latest version of the MEPDG software (version 1.0). The input parameters that are required for MEPDG HMA rehabilitation design, but currently unavailable in the Iowa DOT PMIS were identified. The differences in the specific measurement metrics used and their units for some of the pavement performance measures between the Iowa DOT PMIS and MEPDG were identified and discussed. Based on the results of this study, it is recommended that the Iowa DOT PMIS should be updated, if possible, to include the identified parameters that are currently unavailable, but are required for MEPDG rehabilitation design. Similarly, the measurement units of distress survey results in the Iowa DOT PMIS should be revised to correspond to those of MEPDG performance predictions.

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EXECUTIVE SUMMARY

Reliable and cost-effective design of a rehabilitation project requires the collection and detailed analysis of key data from the existing pavement. The first step in the pavement rehabilitation selection process involves assessing the overall condition of the existing pavement and fully defining the existing pavement problems.

In 2004, the National Cooperative Highway Research Program (NCHRP) released a new pavement design guide called as the Mechanistic-Empirical Pavement Design Guide (MEPDG). The MEPDG is design guide for not only new pavement but also rehabilitated pavement systems to enhance and improve pavement design and many state transportation agencies. MEPDG rehabilitation analysis and design requires not only inputs parameters identical to those used for new pavement design but also additional input parameters related to existing pavement conditions.

Information on many of the factors related to the existing pavement condition can be obtained from the Iowa Department of Transportation (DOT) existing Pavement Management Information System (PMIS); however depending on how regularly data are collected and how recent the latest data are, there may be a need to supplement the pavement management data with more current field survey and testing data.

The primary objective of this study is to systematically evaluate the Iowa DOT's existing PMIS with respect to the input information required for MEPDG rehabilitation analysis and design. To accomplish this objective, methodologies for assessing the existing pavement condition for conducting MEPDG analysis and design were identified and executed primarily based on the review of relevant MEPDG documentation. All of available PMIS data for all interstate and primary roads in Iowa were retrieved from the Iowa DOT PMIS. The retrieved Iowa DOT PMIS databases were compared and evaluated with respect to the input requirements and outputs for the latest version of the MEPDG software (version 1.0). Based on this, specific outcomes of this study include the following:

- Only 4 among 9 input parameters for MEPDG HMA rehabilitation design are available in the current Iowa DOT PMIS.
- Only 3 among 7 input parameters for MEPDG PCC rehabilitation design are available in the current Iowa DOT PMIS.
- The detailed material property inputs (e.g., subgrade resilient modulus, HMA dynamic modulus, etc.) which are required for both new and rehabilitation design in MEPDG are not available in the Iowa DOT PMIS.
- Most of the MEPDG performance measures are available in the Iowa DOT PMIS. However, three CRCP performance measures including punch-out, maximum crack width and minimum crack LTE are not available in the Iowa DOT PMIS.
- Measurement unit for JPCP transverse cracking in Iowa DOT PMIS is different from that predicted by MEPDG.
- Measurement units for HMA pavement alligator and thermal (transverse) cracking in Iowa DOT PMIS are different from those predicted by MEPDG.

- Pavement distress information before 1992 is not available in the Iowa DOT PMIS.
- Detailed information related to pavement distress repair activities are not recorded in the Iowa DOT PMIS.

Based on the results of this research, the following recommendations are made:

- The Iowa DOT PMIS should be updated to include the identified unavailable parameters including detailed material properties, existing distress condition for rehabilitation, and detailed distress repair activities such as the type and time of repair as well as the distress measurements before and after repair.
- MEPDG input material properties for rehabilitation design in Iowa should be selected in accordance with MEPDG recommendations as well as availability of local resources.
- Measurement units of distress survey results in Iowa DOT PMIS should be revised to correspond to those of MEPDG performance predictions.

INTRODUCTION

Reliable and cost-effective design of a rehabilitation project requires the collection and detailed analysis of key data from the existing pavement. Such data are often categorized as follows: (1) traffic lane pavement condition (e.g., distress, smoothness, surface friction, and deflections), (2) shoulder pavement condition, (3) past maintenance activities, (4) pavement design features (e.g., layer thickness, shoulder type, joint spacing, and lane width), (5) geometric design features, (6) layer material and subgrade soil properties, (7) traffic volumes and loadings, (8) climate, and (9) miscellaneous factors (e.g., utilities and clearances).

The data types required for analysis using the Mechanistic-Empirical Pavement Design Guide (MEPDG) range from simple data, such as the pavement design features and pavement geometrics, to detailed data obtained from destructive testing (e.g., Hot Mix Asphalt (HMA) dynamic modulus and Portland Cement Concrete (PCC) elastic modulus), nondestructive testing (e.g., Falling Weight Deflectometer (FWD) testing), and drainage surveys. The project-level evaluation program incorporated into the Design Guide covers three common pavement types – flexible, rigid, and composite.

Overall pavement condition and problem definition can be determined by evaluating the following major aspects of the existing pavement: (1) structural adequacy (load related), (2) functional adequacy (user related), (3) subsurface drainage adequacy, (4) material durability, (5) shoulder condition, (6) extent of maintenance activities performed in the past, (7) variation of pavement condition or performance within a project, and (8) miscellaneous constraints (e.g., bridge and lateral clearance and traffic control restrictions).

The first step in the pavement rehabilitation selection process involves assessing the overall condition of the existing pavement and fully defining the existing pavement problems. To avoid making an inaccurate assessment of the problem, the engineer should collect and evaluate sufficient information about the pavement. Nondestructive testing (NDT) data such as FWD, Dynamic Cone Penetrator (DCP), etc. and profile testing should be considered to assist in making decisions related to timing of the improvement and additional data collection efforts needed. Information on many of the factors related to the existing pavement condition can be obtained from the Iowa Department of Transportation (DOT) existing Pavement Management Information System (PMIS); however depending on how regularly data are collected and how recent the latest data are, there may be the need to supplement the pavement management data with more current field survey and testing data.

The objective of this research is to evaluate the type, accuracy, and timeliness of information collected in the Iowa DOT PMIS regarding the representative in-service pavements in Iowa. Based on this, recommendations will be made with respect to updating the PMIS with more current field survey and testing data to facilitate the implementation of Mechanistic-Empirical Pavement Design Guide (MEPDG) developed by National Cooperative Highway Research Program (NCHRP) 1-37A (2004).

ASSESSMENT OF EXISTING PAVEMENT CONDITION FOR MEPDG

The assessment methodologies of the existing pavement condition for conducting MEPDG analysis and design was carried out primarily based on the review of MEPDG documentation, i.e., NCHRP 1-37 A report. Published research articles, technical presentations and project reports related to MEPDG, especially over the last few years, were also searched and reviewed. A comprehensive review was undertaken with the following objectives:

- Identify the data to be collected and the steps for determining the assessment of the pavement's current structural or functional condition suggested in NCHRP 1-37A;
- Examine the methodology to obtain the data for the assessment of the pavement condition;
- Locate the design requirements for rehabilitation design with MEPDG methodology;
- Summarize recent research activities related to implementation of MEPDG.

The information obtained from the literature review under each of these four categories is discussed at length below.

Data and Steps for Determining the Assessment of the Pavement Condition

NCHPR 1-37A report (2004) suggested that overall pavement condition and problem definition can be 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.
- Extent of maintenance activities performed in the past.
- Variation of pavement condition or performance within a project.
- 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 functional category relates to the surface and subsurface characteristics and properties that define the smoothness of the roadway, or to those surface characteristics that define the frictional resistance or other safety characteristics of the pavement's surface. The other aspects of the existing pavement should be informant because these may affect both structure and functional condition and the selecting feasible rehabilitation alternatives. However, it should be noted that the data in structural category, such as existing distress, nondestructive and destructive testing, will be used in mechanistic-empirical design of rehabilitation alternatives.

The NCHRP 1-37 A report also suggested a comprehensive checklist of factors for the assessment of pavement condition considering those major aspects of the existing pavement as shown in Table 1. Even though this list should be modified to suit the project's specific needs, it is vital that the agencies develop procedures and guidelines for answering the questions on their list.

Table 1. Checklist of factors used in overall pavement condition assessment (NCHRP, 2004)

Facet	Factors	Description
Structural adequacy	Existing distress	1. Little or no load/fatigue-related distress 2. Moderate load/fatigue-related distress (possible deficiency in load-carrying capacity) 3. Major load/fatigue-related distress (obvious deficiency in current load-carrying capacity) 4. Load-carrying capacity deficiency: (yes or no)
	Nondestructive testing (deflection testing)	1. High deflections 2. Are backcalculated layer moduli reasonable? 3. Are joint load transfer efficiencies reasonable?
	Nondestructive testing (GPR testing)	1. Determine layer thickness
	Nondestructive testing (profile testing)	1. Determine joint/crack faulting
	Destructive testing	1. Are cores strengths and condition reasonable? 2. Are the layer thicknesses adequate?
	Previous maintenance performed	Minor, Normal, Major
	Has lack of maintenance contributed to structural deterioration?	Yes, No, Describe_________________
Functional adequacy	Smoothness Cause of smoothness deficiency	Measurement ______________ Very Good, Good, Fair, Poor, Very Poor Foundation movement Localized distress or deterioration Other
	Noise	Measurement ______________ Satisfactory, Questionable, Unsatisfactory
	Friction resistance	Measurement ______________ Satisfactory, Questionable, Unsatisfactory
Subsurface drainage	Climate (moisture and temperature region)	Moisture throughout the year • Seasonal moisture • Very little moisture • Deep frost penetration • Freeze-thaw cycles • No frost problems
	Presence of moisture-accelerated distress	Yes, Possible, No
	Subsurface drainage facilities	Satisfactory, Marginal, Unsatisfactory
	Surface drainage facilities	Satisfactory, Marginal, Unsatisfactory
	Has lack of maintenance contributed to deterioration of drainage facilities?	Yes, No, Describe_________________
Materials durability	Presence of durability-related distress (surface layer)	1. Little or no durability-related distress 2. Moderate durability-related distress 3. Major durability-related distress
	Base erosion or stripping	1. Little or no base erosion or stripping 2. Moderate base erosion or stripping 3. Major base erosion or stripping
	Nondestructive testing (GPR testing)	1. Determine areas with material deterioration/moisture damage (stripping)

Table 1. (continued) Checklist of factors used in overall pavement condition assessment

Facet	Features	Description
Shoulder adequacy	Surface condition	1. Little or no load-associated/joint distress 2. Moderate load-associated/joint distress 3. Major load-associated/joint distress 4. Structural load-carrying capacity deficiency: (yes or no)
	Localized deteriorated areas	Yes, No Location:
Condition/ performance variability	Does the project section include significant deterioration of the following: • Bridge approaches • Intersections • Lane to lane • Cuts or fills	 Yes, No Yes, No Yes, No Yes, No
	Is there a systematic variation in pavement condition along project (localized variation)?	Yes, No
	Systematic lane to lane variation in pavement condition	Yes, No
Miscellaneous	PCC joint damage: • Is there adequate load transfer (transverse joints)? • Is there adequate load transfer (centerline joint)? • Is there excessive centerline joint width? • Is there adequate load transfer (lane-shoulder)? • Is there joint seal damage? • Is there excessive joint spalling (transverse)? • Is there excessive joint spalling (longitudinal)? • Has there been any blowups?	 Yes, No Yes, No Yes, No Yes, No Yes, No Yes, No Yes, No Yes, No
	Past maintenance • Patching • Joint resealing	 Yes, No Yes, No
	Traffic capacity and geometrics • Current capacity • Future capacity • Widening required now	 Adequate, Inadequate Adequate, Inadequate Yes, No
Constraints?	Are detours available for rehabilitation construction?	Yes, No
	Should construction be accomplished under traffic?	Yes, No
	Can construction be done during off-peak hours?	Yes, No, Describe________________
	Bridge clearance problems	Describe________________
	Lateral obstruction problems	Describe________________
	Utilities problems	Describe________________
	Other constraint problems	Describe________________

The data to be collected for conducting pavement assessment can be categorized into historic data and benchmark data (NCHRP, 2004). Any data collected before pavement evaluation, regardless of type, is historic. It includes site-, design-, and construction-related data assembled from inventory, monitoring, and maintenance data tables established throughout the pavement life. Data collected during pavement evaluation, such as visual surveys, nondestructive, and destructive testing are described as benchmark data. The same data obtained from the files containing test data collected during construction is described as historic. A successful and thorough pavement evaluation program will require both benchmark and historic data, since some data by definition will always remain historic (e.g., traffic). However, in situations where the data can be obtained from both sources, benchmark data will tend to be more reliable.

The steps for determining an assessment of the pavement’s current structural or functional condition are (APT, 2001):

1. Historic data collection (records review).

2. First field survey.
3. First data evaluation and determination of additional data requirements.
4. Second field survey.
5. Laboratory characterization.
6. Second data evaluation.
7. Final field evaluation report.

Steps 1 and 2: Historic Data Collection and First Field Survey

The assessment of pavement should begin with an assembly of historic data and preferably some benchmark data. Steps 1 and 2 of the field collection and evaluation plan should, as a minimum, fulfill all the data requirements to perform an overall problem definition. The following activities should be performed:

- Review construction and maintenance files to recover and extract information and data pertinent to pavement performance and response.
- Review previous distress surveys and the pavement management records, if available, to establish performance trends and deterioration rates.
- Review previous deflection surveys.
- Review previous pavement borings and laboratory test results of pavement materials and subgrade soils.
- Perform a windshield survey or an initial surveillance of the roadway's surface, drainage features, and other related items.
- Identify roadway segments with similar or different surface and subsurface features using the idealized approach (discussed in the next section of this chapter). In other words, isolate each unique factor that will influence pavement performance.
- Identify the field testing/materials sampling requirements for each segment and the associated traffic control requirements.
- Determine if the pavement performed better or worse than similar designs.

The information gathered in this step can be used to divide the pavement into units with similar design features, site conditions, and performance characteristics for a more detailed pavement evaluation.

Step 3: First Data Evaluation and Determination of Additional Data Requirements

Using the information and data gathered in steps 1 and 2, a preliminarily overall pavement condition analysis can be performed. If the information and data gathered is inadequate, then more detailed data will be required to determine the extent and severity of the pavement condition. Step 3 is very important since it helps agencies reduce considerably the list of additional data requirements, making the overall pavement assessment and problem definition process more cost-effective.

Step 4 and 5: Second Field Survey and Laboratory Characterization

Steps 4 and 5 involve conducting detailed measuring and testing, such as coring and sampling, smoothness measurement, deflection testing, skid resistance measurement, drainage tests, and measuring vertical clearances on the project under evaluation. The data collected at this stage should be guided by the data needs determined at the end of the first evaluation phase in step 3. Steps 4 and 5 will also involve conducting tests such as material strength, resilient modulus, permeability, moisture content, composition, density, and gradations, using samples obtained from the second field survey. Field data collection, laboratory characterization, and data manipulation should be done according to established guidelines from test standards such as AASHTO, ASTM, LTPP, SHRP, and State and local highway agencies.

Step 6 and 7: Second Data Evaluation and Final Field Evaluation Report

Using the data collected during steps 1 through 5, the final pavement evaluation and overall problem definition can be conducted. Step 7 documents the details of the pavement evaluation process, the data obtained specifying levels of input, and problems identified in a final evaluation report.

Methodology for Obtaining Data for Pavement Condition Assessment

The data and information required for the assessment of the pavement condition can be obtained directly from the agency's historic data tables (inventory or monitoring tables) or by conducting visual surveys, performing nondestructive testing, and performing destructive testing as part of pavement evaluation (NCHRP, 2004).

The activities performed as part of assembling historic data from inventory or monitoring data files include a review of past construction and maintenance data files to recover and extract information and data pertinent to pavement design features, material properties, and construction parameters, borings logs, and laboratory testing of layer materials and subgrade soils. The review should also include past pavement management records for information on past distress surveys and maintenance activities. A thorough review of past records could also yield information on pavement constraints such as bridge clearances and lateral obstruction. Two kinds of information that should be assembled as part of the historic data are traffic and climate-related data. The traffic data required include past and future traffic estimates that are required as input for determining current and future pavement structural adequacy. Climate variables such as precipitation and freeze-thaw cycles may also be required as inputs for rehabilitation design and structural adequacy analysis.

Visual Surveys

Visual surveys range from a casual windshield survey conducted from a moving vehicle to the more detailed survey that involves trained engineers and technicians walking the entire length of the project (or selected sample areas) and measuring and mapping out all distresses identified on the pavement surface, shoulders, and drainage systems (APT, 2001). Recently, automated visual survey techniques have become more common and are being adopted for distress surveys and pavement condition evaluation.

Although pavement condition is defined in different ways by different agencies, it almost always requires the identification of several distress types, severities, and amounts through on-site visual survey. Distress Identification Manual for the Long-Term Pavement Performance Project (SHRP, 1993) is the one of distress manual having broader applications and providing a common language for describing distress on different type of pavements.

Nondestructive Test

NDT is a term used to describe the examination of pavement structure and materials properties through means that do not induce damage or property changes to the structure (NCHRP, 2004). NDT ranges from simple techniques such as using Ground Penetrating Radar (GPR) to determine in-situ layer thickness and condition, profile testing to determine pavement surface smoothness, friction testing to determine pavement surface-vehicle tire skid resistance, through to the well-established method of deflection testing, using a FWD (Shahin, 1994).

NDT typically has the following advantages (AASHTO, 1993; Shahin, 1994):

- Reduces the occurrence of accidents due to lane closures.
- Reduces costs.
- Improves testing reliability.
- Provides vital information for selecting between rehabilitation options.
- Provides data for rehabilitation (overlay) design.
- Quickly gather data at several locations.

Although NDT has many advantages, it also has some limitations as follows (FAA, 1994):

- Require other methods to evaluate the functional condition of the pavement such as visual condition, smoothness, and friction characteristics.
- Require other important engineering properties of the pavement layers, such as grain-size distribution of the subgrade to determine swelling and heaving potential.
- Give different results at different measurement time in a year due to climatic variations
- Need some caution to evaluate the selected pavement types such as continuously reinforced concrete pavement, post-tensioned concrete, and pre-tensioned concrete due to the model dependencies of NDT software.

Nondestructive testing equipment includes both deflection and non-deflection testing equipment (FAA, 1994). Deflection measuring equipment for nondestructive testing of pavements can be broadly classified as static or dynamic loading devices. Dynamic loading equipment can be further classified according to the type of forcing function used, i.e., vibratory or impulse devices. Non-deflection measuring equipment that can supplement deflection testing includes ground-penetrating radar, infrared thermography, and devices that measure surface waves.

Destructive Test

Destructive tests require the physical removal or damage of pavement layer material to obtain a sample (either disturbed or undisturbed) for laboratory characterization or to conduct an in-situ DCP test (NCHRP, 2004). Destructive testing ranges from simple tests such as coring (and determining the pavement layer thicknesses by measuring core lengths) to performing dynamic modulus testing on retrieved Asphalt Concrete (AC) cores or determining the elastic modulus and strength of PCC cores. Other forms of destructive testing that are less common are:

- Trenching of HMA or AC pavements to determine material condition and permanent deformation.
- Lifting of slabs of jointed concrete pavements (JCP) to determine subsurface material conditions.

Trenching consists of cutting a full depth, 4- to 6-in-wide strip of pavement, full width of a traffic lane, and removing it to observe the condition of the different pavement layers over time. If rutting is present, it allows the engineer to determine where the rutting is located and the cause of rutting (consolidation or plastic flow). Trenching also allows the engineer to determine if and where stripping-susceptible asphalt layers lie in the pavement section. Destructive tests such as trenching generally help improve evaluation of the causes of surface distresses.

Destructive testing has many limitations, particularly when conducted on moderate to heavily trafficked highway systems (e.g., risk to testing personnel). Practical restraints—in terms of time and money—severely limit the number and variety of destructive tests conducted on routine pavement evaluation studies (AASHTO, 1993; Shahin, 1994). Destructive testing also has some vital advantages, including the observation of subsurface conditions of pavements layers and bonding between layers. Destructive testing could also include the milling of an HMA overlay in an HMA/PCC composite pavement to make it possible to visually examine the joint area of the PCC for deterioration.

Design Requirements for Rehabilitation Design with MEPDG Methodology

HMA and PCC can be used to remedy functional or structural deficiencies of existing pavements (NCHRP, 2004). It is important for the designer to consider several aspects, including the type of deterioration present, before determining the appropriate rehabilitation strategy to adopt. Several different rehabilitation options using HMA and PCC can be applied to existing pavements to extend their useful service life. These range from thin surface treatments and the combination of repair and preventive treatments to structural overlays of existing flexible, composite, or rigid pavements and from in-place recycling of existing pavement layers followed by placement of a

HMA or PCC. These strategies are commonly used to remedy functional, structural, or other inadequacies.

The mechanistic-empirical design of rehabilitated pavements requires an iterative, hands-on approach by the designer (NCHRP, 2004). The designer must select a proposed trial rehabilitation design and then analyze the design in detail to determine whether it meets the applicable performance criteria established by the designer. If a particular trial rehabilitation design does not meet the performance criteria, the design is modified and reanalyzed until it meets the criteria. The designs that meet the applicable performance criteria are then considered feasible from a structural and functional viewpoint and can be further considered for other evaluations, such as life cycle cost analysis (LCCA).

Most of inputs parameters are identical to those used for new pavement design. However, the additional input parameters are required in mechanistic-empirical design of rehabilitation alternatives. All of these parameters value can be obtained from the assessment procedure for existing pavement condition. Input data used for the design of rehabilitation with HMA (or AC) and PCC in MEPDG are summarized in Tables 2 and 3, respectively.

Table 2. Design input and requirements for rehabilitation design with HMA (NCHRP, 2004)

General Description	Variable	Rehabilitation Type		
		HMA Overlay of Existing HMA Surfaced Pavement	HMA Overlay of Fractured PCC Pavement	HMA Overlay of Existing Intact PCC Pavement
General information	Project name and description	Yes	Yes	Yes
	Design life, years	Yes	Yes	Yes
	Existing pavement construction date	Yes	Yes	Yes
	Pavement overlay construction date	Yes	Yes	Yes
	Traffic opening date	Yes	Yes	Yes
	Asphalt Concrete Overlay	Yes	Yes	Yes
Site/project identification	Location of the project	Yes	Yes	Yes
	Project and section identification	Yes	Yes	Yes
	Functional class	Yes	Yes	Yes
Analysis parameters				
	Initial smoothness	Yes	Yes	Yes
	Performance criteria	Yes (table 3.6.3)	Yes (table 3.6.3)	Yes (table 3.6.3)
Climate	Climatic parameters: temperature, moisture, depth to water table, etc. (same inputs required for new pavement designs)	Yes (see PART 2, Chapter 3)	Yes (see PART 2, Chapter 3)	Yes (see PART 2, Chapter 3)
	Hourly profiles of temperature distribution through PCC slab	NA[1]	NA	Yes
	Hourly temperature and moisture profiles (including frost depth calculations) through the other pavement layers	Yes	Yes	Yes
	Temperature at the time of PCC set for JPCP and CRCP overlay design	NA	NA	Yes
	Monthly or semi-monthly (during frozen or recently frozen periods) predictions of layer moduli for asphalt, unbound base/subbase, and subgrade layers	Yes	Yes	Yes
	Mean annual freezing index, number of wet days, number of freeze-thaw cycles	Yes	Yes	Yes
	Mean monthly relative humidity	Yes	Yes	Yes
Traffic	Axle load distribution for each axle type; same input elements required for new pavement designs.	Yes (see PART 2, Chapter 4)	Yes (see PART 2, Chapter 4)	Yes (see PART 2, Chapter 4)
Drainage and surface properties	Pavement surface layer shortwave absorptivity	Yes	Yes	Yes
	Potential for infiltration	Yes	Yes	Yes
	Pavement cross slope	Yes	Yes	Yes
	Length of drainage path	Yes	Yes	Yes
Design Features	PCC pavement type dependent	NA	NA	Yes (see PART3, Chapter 4)

Table 2. (continued) Design input and requirements for rehabilitation design with HMA

General Description	Variable	Rehabilitation Type		
		HMA Overlay of Existing HMA Surfaced Pavement	HMA Overlay of Fractured PCC Pavement	HMA Overlay of Existing Intact PCC Pavement
Distress Potential	Medium and High severity sealed longitudinal cracks outside wheel path	Yes	Yes	Yes
	Area of medium and high severity patches, % total lane area	Yes	Yes	Yes
	Potholes, % total lane area	Yes	Yes	Yes
Rehabilitation related inputs for existing rigid pavement[2]	Percentage of slabs with cracks prior to overlay before any restoration work is done plus percentage of slabs replaced on the project historically	NA	NA	Yes (for HMA overlays of JPCP only)
	Percentage of slabs with repairs after any pre-overlay restoration work is performed (includes historically replaced/repaired slabs)	NA	NA	Yes (for HMA overlays of JPCP only)
	Number of punchouts per mile	NA	NA	Yes (for HMA overlays of CRCP only)
	Number of punchouts repaired as part of pre-overlay activities per mile	NA	NA	Yes (for HMA overlays of CRCP only)
Foundation Support	Dynamic (FWD) Backcalculated modulus of subgrade reaction, k-value	NA	NA	Optional This value may be entered if known from FWD testing along with the month in which the test was performed. It is used to scale the k-value internally calculated by Design Guide software.

[1] NA = Not applicable.
[2] Detailed discussions on the exact inputs pertaining to this category and how they relate to the design procedure are provided under sections 3.6.4 through 3.6.6.

Table 3. Design inputs and requirements for rehabilitation design with PCC (NCHRP, 2004)

General Description	Variable	Rehabilitation Type		
		Existing JPCP subjected to CPR	JPCP Overlays[1]	CRCP Overlays[2]
Drainage and surface properties	Pavement surface layer (PCC) shortwave absorptivity	➼	➼	➼
	Potential for infiltration	➼	➼	➼
	Pavement cross slope	➼	➼	➼
	Length of drainage path	➼	➼	➼
Layer definition and material properties	Layer number, description, and material type	➼	➼	➼
	Layer thickness	➼	➼	➼
	Elastic modulus	➼	➼	➼
	Flexural, compressive, and tensile strength	➼	➼	➼
	Ultimate shrinkage	➼	➼	➼
	Unit weight, Poisson's ratio	➼	➼	➼
	Coefficient of thermal expansion	➼	➼	➼
	Thermal conductivity, heat capacity, etc.	➼	➼	➼
Design features	Permanent curl/warp (effective temperature difference) in PCC slab due to construction curling and moisture warping	➼	➼	➼
	Transverse joint spacing (average or random)	➼	➼	
	Transverse joint sealant type	➼	➼	
	Dowel diameter and spacing	➼	➼	
	Edge support (tied PCC, widened lane, slab width, etc.)	➼	➼	➼
	Lane-shoulder joint load transfer efficiency (LTE) (for tied PCC shoulders)	➼	➼	➼
	Slab width (for widened slabs)	➼	➼	
	Number of years after which PCC/base interface is unbonded N_{bond} (for JPCP with a stabilized base)	➼	➼	
	Base erodibility index	➼	➼	➼
	Total longitudinal steel cross-sectional area as percent of PCC slab cross-sectional area			➼
	Diameter of longitudinal reinforcing steel			➼
	Depth of steel placement from pavement surface			➼
	PCC slab/base friction coefficient[1]			➼
	Crack spacing (mean and standard deviation)			➼

Table 3. (continued) Design inputs and requirements for rehabilitation design with PCC (NCHRP, 2004)

General Description	Variable	Rehabilitation Type		
		Existing JPCP subjected to CPR	JPCP Overlays[1]	CRCP Overlays[2]
Rehabilitation	Existing distress—percent slabs with transverse cracks plus previously replaced slabs	➼		
	Percent of slabs with repairs after restoration	➼		
	Foundation support—modulus of subgrade reaction	➼		
	Month modulus of subgrade reaction was measured	➼		

Summary of Research Activities Related to MEPDG Implementation

Since the NCHRP released the MEPDG for design of New and Rehabilitated Pavement Structures in June of 2004, numerous research efforts have been undertaken to implement MEPDG. The Federal Highway Administration (FHWA) considers implementation of MEPDG a critical element in improving the National Highway System (FHWA, 2009). FHWA organized a Design Guide Implementation Team (DGIT) to immediately begin the process of informing, educating, and assisting FHWA field offices, State Highway Agencies, Industry, and others about the new design guide.

At the request of the AASHTO Joint Task Force on Pavements (JTFP), NCHRP initiated NCHRP 1-40: Facilitating the Implementation of the Guide for the Design of New and Rehabilitated Pavement Structures following NCHRP 1- 37 A. NCHHRP 1-40 consist of several independent NCHRP projects as summarized in Table 4. NCHRP will also continue to perform other tasks identified by the project panel and the AASHTO Joint Technical Committee on Pavements in support of the implementation and adoption of the guide and software.

Table 4. Summary of NCHRP projects related to MEPDG implementation (TRB, 2009)

Project No.	Description (Subject)	Status
NCHRP 1-40	Facilitating the Implementation of the Guide for the Design of New and Rehabilitated Pavement Structures	Active
NCHRP 1-40A	Independent Review of the Recommended Mechanistic-Empirical Design Guide and Software	Complete
NCHRP 1-40B	User Manual and Local Calibration Guide for the Mechanistic-Empirical Pavement Design Guide and Software	Active
NCHRP 1-40D	Technical Assistance to NCHRP and NCHRP Project 1-40A: Versions 0.9 and 1.0 of the M-E Pavement Design Software	Active
NCHRP 1-40E	Refining and upgrading the design software on a continuing basis	Plan
NCHRP 1-40H	A practical guide for mechanistic-empirical pavement design	Plan
NCHRP 1-40J	Support for the Mechanistic Design Guide Lead States and related state DOT activities	Plan

In order to effectively and efficiently transition to the MEPDG, many state DOTs also adopt or will adopt a MEPDG implementation plan to meet their local conditions (Nantung et. al., 2005; Uzan et. al., 2005; Ceylan et. al., 2006).

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Table 5. Recommendations for pavement evaluation and rehabilitation design in MEPDG (NCHRP, 2006)

Type	Recommendation
Essential	1. Use *in situ* material properties obtained from pavement evaluation as input parameters for rehabilitation design. 2. Give better advice on HMA stiffness prediction for existing pavements. 3. Give advice on other uses of the FWD, in addition to the determination of pavement layer stiffnesses. 4. Specify closer spacing for FWD testing, coring, and DCP testing for the various design levels. 5. Investigate and carry out more research of laboratory-resilient modulus predictions of unbound materials from field values determined from FWD data using various conversion factors. 6. Improve the procedures for structural evaluation of concrete pavements. 7. Improve the determination of LTE between slabs and across cracks. 8. Check and correct, as appropriate, the detail concerning base erodibility, upward curl, and overburden on subgrade in relation to the computations for faulting in concrete slabs.
Desirable	Give recommendations on the effect of interlayer bond condition on pavement evaluation, life prediction, and recommended treatment.

Several studies have attempted to evaluate the pavement performance prediction models included in the MEDPG for rehabilitation design (Darter, et. al., 2005; Galal and Chehab, 2005; Rodezno et. al., 2005). However, only very few studies have focused on the development of detailed data collection procedure and pavement condition database for MEPDG rehabilitation design and analysis.

Maher et al. (2005) conducted a comparison of FWD backcalculated modulus with the dynamic modulus of HMA cores extracted from the same FWD test location. FWD backcalculation results showed excellent correlation with the master curve developed from the laboratory test results when the loading frequency of the FWD was assumed to be 16. 7 hertz. Amara et al. (2007) evaluated the procedures proposed by the MEPDG to characterize existing HMA dynamic modulus using FWD testing as well as laboratory testing for three different input levels in the MEPDG software. They concluded that Level 1 data (using FWD) is necessary to obtain reliable estimates of the properties of the existing HMA since FWD testing can only measure the overall condition of the entire HMA layer.

EVALUATION OF THE IOWA DOT PMIS FOR MEPDG REHABILITATION ANALYSIS AND DESIGN

The primary objective of this study is to systematically evaluate the Iowa DOT's existing PMIS with respect to the input information available for MEPDG analysis and design. To accomplish this objective, the PMIS data, from 1992 to 2006, for all interstate and primary roads in the state were retrieved from the Iowa DOT PMIS. Since the Iowa DOT PMIS has been developed from

1994 for all Federal Aid Eligible (FAE) roads in the State, the pavement distress information before 1992 was not available.

Each year, the PMIS database contains more than 3,000 data records including detailed information for HMA, Jointed plain concrete pavement (JPCP), Continuously Reinforced Concrete Pavement (CRCP) and composite pavements. For example, the retrieved dataset from the 2006 PMIS database (summarized in Table 6) contains 3689 records. Each data record consist of lots of information including traffic, pavement material and structure, distress survey results close to about 270 columns in an Excel Spreadsheet.

Table 6. Summary of data records for interstate and primary roads in 2006 Iowa PMIS

Type of Pavement	Number of Data Points
HMA	448
JPCP	1,316
CRCP	22
Composite	1,903
Total	3,689

MEPDG Software Input Requirements for Rehabilitation Design

The available information from the Iowa DOT PMIS were compared to the rehabilitation related input information required for running the latest version of the MEPDG software (version 1.0). These comparisons for HMA and PCC rehabilitation design are summarized in Tables 7 and 8, respectively. Only 4 among 9 input parameters of MEPDG HMA rehabilitation and only 3 among 7 input parameters of MEPDG PCC rehabilitation are available in the current Iowa DOT PMIS. The detailed material property inputs (e.g., subgrade resilient modulus, HMA dynamic modulus, etc.) which are required for both new and rehabilitation design in MEPDG are not available in the Iowa DOT PMIS. Tables 9 to 15 summarize types of laboratory and filed tests to be determined for materials characterization considering the availability and recommendations of MEPDG. These results indicate that the Iowa DOT PMIS should be revised/updated to incorporate periodically collected data for the identified unavailable parameters.

Table 7. Summary of input requirements for MEPDG HMA rehabilitation design

<table>
<tr><th rowspan="2">General Description</th><th rowspan="2" colspan="2">Variable</th><th colspan="3">Rehabilitation Option</th><th rowspan="2">Iowa PMIS</th></tr>
<tr><th>HMA over PCC</th><th>HMA over PCC (fractured)</th><th>HMA over ACC</th></tr>
<tr><td rowspan="5">Rehabilitation of existing rigid pavement</td><td rowspan="3">Existing distress</td><td>Before restoration, percent slabs with transverse cracks plus previously replaced/repaired slab</td><td>Yes (for HMA over JPCP only)</td><td>N/R [a]</td><td>N/R</td><td>No</td></tr>
<tr><td>After restoration, total percent of slab with repairs after restoration</td><td>Yes (for HMA over JPCP only)</td><td>N/R</td><td>N/R</td><td>No</td></tr>
<tr><td>CRCP punch-out (per mile)</td><td>Yes (for HMA over CRCP only)</td><td>N/R</td><td>N/R</td><td>No</td></tr>
<tr><td rowspan="2">Foundati on support</td><td>Modulus of subgrade reaction (psi / in)</td><td>Yes</td><td>N/R</td><td>N/R</td><td>Yes (Ave. K)</td></tr>
<tr><td>Month modulus of subgrade reaction was measured</td><td>Yes</td><td>N/R</td><td>N/R</td><td>No</td></tr>
<tr><td rowspan="4">Rehabilitation of existing flexible pavement</td><td rowspan="2" colspan="2">At Levels 1, 2, and 3</td><td rowspan="2">N/R</td><td rowspan="2">N/R</td><td>Milled Thickness (in)</td><td>Yes</td></tr>
<tr><td>Placement of geotextile prior to overlay</td><td>No</td></tr>
<tr><td rowspan="2" colspan="2">At Level 3 only</td><td rowspan="2">N/R</td><td rowspan="2">N/R</td><td>Total rutting (in)</td><td>Yes</td></tr>
<tr><td>Subjective rating of pavement condition</td><td>Yes (PCI)</td></tr>
</table>

a. N/R is "Not Required"

Table 8. Summary of input requirements for MEPDG PCC rehabilitation design

General Description	Variable		MEPDG PCC Rehabilitation Option			Iowa PMIS
			Bonded PCC over JPCP	Bonded PCC over CRCP, Unbounded PCC over PCC-	PCC over HMA	
Rehabilitation for existing pavement	Existing distress	Before restoration, percent slabs with transverse cracks plus previously replaced/repaired slab	Yes	N/R[a]	N/R	No
		After restoration, total percent of slab with repairs after restoration	Yes	N/R	N/R	No
		CRCP punch-out (per mile)	N/R	N/R	N/R	No
	Foundation support	Modulus of subgrade reaction (psi / in)	Yes	Yes	Yes	**Yes (Ave. K)**
		Month modulus of subgrade reaction measured	Yes	Yes	Yes	No
	Flexible rehabilitation	Milled thickness (in)	N/R	N/R	Yes	**Yes**
		Subjective rating of pavement condition	N/R	N/R	Yes	**Yes (PCI)**

a. N/R = Not Required

Table 9. Recommended test methods for existing HMA surfaced pavement layers (NCHRP, 2004)

Layer Material	Input	Hierarchical Level		
		1	2	3
Subgrade	Modulus	NDT	Simple Test Correlations	Soil Classification
	Initial ε_p	Trench Data	User Input	User Input
Unbound Base or Subbase	Modulus	NDT	Simple Test Correlations	Soil Classification
	Initial ε_p	Trench Data	User Input	User Input
Chemically Stabilized Materials	Damaged Modulus	NDT	Estimated from Undamaged Modulus	Estimated from Undamaged Modulus
	Undamaged Modulus	Compressive Strength of Field Cores	Estimated from Compressive Strength of Field Cores	Estimated form Typical Compressive Strength
	Fatigue Damage	% Alligator Cracking	% Alligator Cracking	Pavement Rating
Existing Asphalt Layers	Damaged Modulus	NDT	Estimated from Undamaged Modulus	Estimated from Undamaged Modulus
	Undamaged Modulus	HMA dynamic modulus model with Project Specific Inputs	HMA dynamic modulus model with Project Specific Inputs	HMA dynamic modulus model with Agency Historical Inputs
	Fatigue Damage	% Alligator Cracking from Visual Condition Surveys	% Alligator Cracking from visual condition surveys	Pavement Rating
	Initial ε_p	Trench Data	User Input	User Input

Table 10. Recommended test methods for fractured slab analysis (NCHRP, 2004)

Layer Material	Input	Hierarchical Level		
		1	2	3
Subgrade	Modulus	NDT	Simple Test Correlations	Soil Classification
	Initial ε_p	Trench Data	User Input	User Input
Existing Unbound Base or Subbase	Modulus	NDT	Simple Test Correlations	Soil Classification
	Initial ε_p	Trench Data	User Input	User Input
Existing Asphalt Base or Subbase	Dynamic Modulus	NDT	HMA dynamic modulus model with Project Specific Inputs	HMA dynamic modulus model with Agency Historical Inputs
	Initial ε_p	Trench Data	User Input	User Input
Fractured Slab	Modulus	Tabulated with NDT Quality Assurance (see table 3.6.16)	None	Tabulated Based on Process and Crack Spacing (see table 3.6.17)

Table 11. Recommended test methods for HMA overlaid PCC pavements (NCHRP, 2004)

Layer Material	Input	Hierarchical Level 1	Hierarchical Level 2	Hierarchical Level 3
Subgrade	Modulus	NDT	Simple Test Correlations	Soil Classification
Existing Unbound Base or Subbase	Modulus	NDT	Simple Test Correlations	Soil Classification
Existing Asphalt Base or Subbase	Dynamic Modulus	NDT	HMA dynamic modulus model with Project Specific Inputs	HMA dynamic modulus model with Agency Historical Inputs
Jointed Plain Concrete Pavement (JPCP)	Elastic Modulus for PCC	Field Core (lab testing) or Backcalculated FWD (adjusted)	Estimated from Compressive Strength of Field Cores	Estimated from Historical Compressive Strength Data
	Modulus of Rupture	Field Beam (lab testing)	Estimated from Compressive Strength of Field Cores	Estimated from Historical Compressive Strength Data
	Past Fatigue Damage	% Slabs Cracked	% Slabs Cracked	Pavement Rating
Continuously Reinforced Concrete Pavement (CRCP)	Elastic Modulus for PCC	Field Core (lab testing) or Backcalculated FWD (adjusted)	Estimated From Compressive Strength of Field Cores	Estimated from Historical Compressive Strength Data
	Modulus of Rupture	Field Beam (lab testing)	Estimated From Compressive Strength of Field Cores	Estimated from Historical Compressive Strength Data
	Past Fatigue Damage	Punchouts & Repairs /mile	Punchouts & repairs /mile	Pavement Rating
Jointed Reinforced Concrete Pavement (JRCP)	Elastic Modulus for PCC	Field Core (lab testing) or Backcalculated FWD (adjusted)	Estimated from Compressive Strength of Field Cores	Estimated from Historical Compressive Strength Data

Table 12. Existing HMA dynamic modulus (E*) estimation at various hierarchical input levels for PCC rehabilitation design (NCHRP, 2004)

Material Group Category	Type Design	Input Level	Description
Asphalt Materials (existing layers)	Rehab	1	• Not applicable to PCC
		2	• Not applicable to PCC
		3	• Use typical estimates of mix modulus prediction equation (mix volumetric, gradation and binder type) to develop undamaged master curve with aging for site layer. • Using results of distress/condition survey, obtain estimate for pavement rating (excellent, good, fair, poor, very poor) • Use a typical tabular correlation relating pavement rating to pavement layer damage value, d_j. • In sigmoidal function, δ is minimum value and α is specified range from minimum. Define new range parameter α' to be: $\alpha' = (1-dj)\,\alpha$ • Develop field damaged master curve using α' rather than α

Table 13. Data required for characterizing existing PCC slab and chemically stabilized layers (NCHRP, 2004)

Input Data[1]	Hierarchical Level		
	1	2	3
Unit weight	Obtained from coring and testing	N/A	Estimate from historical agency data
Poisson's ratio	Obtained from coring and testing	N/A	Estimate from historical agency data (see Part 2, Chapter 2)
Existing PCC slab design elastic modulus (applicable in situations where the existing intact PCC slab is considered the base)[2]	The test elastic modulus E_{TEST} is obtained from (1) coring the intact slab and laboratory testing for elastic modulus or (2) by backcalculation (using FWD deflection data from intact slab and layer thicknesses) and multiplying by 0.8 to convert from dynamic to static modulus. The design existing PCC slab elastic modulus is determined as follows: $E_{BASE/DESIGN} = C_{BD} * E_{TEST}$ where E_{TEST} is the static elastic modulus obtained from coring and laboratory testing or backcalculation of uncracked intact slab concrete and C_{BD} is a factor based on the overall PCC condition as follows: • C_{BD} = 0.42 to 0.75 for existing pavement in overall "good" structural condition. • C_{BD} = 0.22 to 0.42 for existing pavement in "moderate" condition. • C_{BD} = 0.042 to 0.22 for existing pavement in "severe" condition. Pavement condition is defined in table 3.7.12. A maximum $E_{BASE/DESIGN}$ of 3 million psi is recommended due to existing joints even if few cracks exist.	$E_{BASE/DESIGN}$ obtained from coring and testing for compressive strength. The compressive strength value is converted into elastic modulus as outlined in Part 2, Chapter 2. The design elastic modulus is obtained as described for level 1	$E_{BASE/DESIGN}$ estimated from historical agency data and local experience for the existing project under design
Rubblized PCC (applicable in situations where the existing intact PCC slab is considered the base)[2]	N/A	N/A	$E_{BASE/DESIGN}$ typically ranges from 50,000 to 150,000 psi. It could also be estimated from historical agency data and local experience
Chemically stabilized materials elastic modulus	Obtained from coring and testing for elastic modulus as outlined in Part 2, Chapter 2	Obtained from coring and testing for compressive strength. The compressive strength value is converted into elastic modulus as outlined in Part 2, Chapter 2.	Estimated from historical agency data and local experience
Thermal conductivity	N/A	N/A	Estimate from historical data
Heat capacity	N/A	N/A	Estimate from historical data

Table 14. Data required for characterizing unbound granular materials, subgrade soils, and bedrock resilient modulus (NCHRP, 2004)

Input Data	Hierarchical Level		
	1	2	3
Resilient modulus	There is no laboratory testing procedure for resilient modulus available for level 1 rigid pavements. Level 1 rigid pavement rehabilitation parameter is deflection data obtained from FWD testing and used for backcalculation of modulus of subgrade reaction (Table 3.7.13)	Data is obtained by running field tests for DCP (for a given month) or laboratory testing of bulk samples obtained from the existing pavement for CBR, R-Value, and AASHTO soil classification. Resilient modulus is then estimated using models/correlations with the test values as input. The seasonal resilient moduli are determined by: (1) Entering the resilient modulus at optimum water content and let the EICM do the seasonal adjustments, (2) Enter 12 resilient moduli (one for each month), or (3) Enter 1 representative resilient modulus and this will be used throughout the year.	Regional or typical values are assumed from historical agency data for design. Seasonal values are determined as follows: (1) Enter the resilient modulus at optimum water content and let the EICM do the seasonal adjustments, (2) Enter 1 representative resilient modulus value to be used for all seasons (no moisture content is required)

Table 15. Information required for unbound granular materials, unbound soil material, subgrade/bedrock (used in EICM) (NCHRP, 2004)

Input	Hierarchical Level		
	1	2	3
Plasticity index	Obtained through laboratory testing of bulk samples	N/A	Estimate from historical agency data
Percent passing No. 200 sieve	Obtained through laboratory testing of bulk samples	N/A	Estimate from historical agency data
Percent passing No. 4 sieve	Obtained through laboratory testing of bulk samples	N/A	Estimate from historical agency data
Sieve size for with 60 percent of the subgrade material is retained (D60)	Obtained through laboratory testing of bulk samples	N/A	Estimate from historical agency data
Dry thermal conductivity	Obtained through testing of bulk samples	N/A	Estimate from historical agency data
Dry heat capacity	Obtained through testing of bulk samples	N/A	Estimate from historical agency data
Unbound granular/soil material characteristic curve parameters (a, b, c, and hr)[1]	Obtained through laboratory testing of bulk samples	N/A	Estimate from historical agency data

MEPDG Software Input Requirements for Rehabilitation Design

Since the Iowa DOT PMIS has been developed from 1994 for all FAE roads in the State, the pavement distress information before 1992 was not available. First, the distress types and units of distress types collected from distress survey results and recorded in Iowa DOT PMIS were compared to those of MEPDG performance predictions (see Table 16).

In general, most of the MEPDG performance measures are also available in the Iowa DOT PMIS. However, three performance measures for CRCP such as punch-out, maximum crack width and minimum crack Load Transfer Efficiency (LTE) are not available in the Iowa DOT PMIS. Also, the measurement units for JPCP transverse cracking as well as HMA alligator and thermal (transverse) cracking reported by MEPDG cannot be compared with that of Iowa DOT PMIS. The PMIS data are reported in S. I units whereas English units are used in MEPDG, although this is not a big concern.

Table 16. Comparison of MEPD output results to Iowa PMIS

Type of Pavement		Performance Model	MEPDG	Iowa PMIS
PCC	JPCP	Faulting	inch	millimeter
		Transverse cracking	% slab cracked	number of crack / km
		Smoothness	in/mile	m/km
	CRCP	*Punch-out*	number of punch-out/mile	N/A[a]
		Maximum crack width	mils	N/A[a]
		Minimum crack LTE	%	N/A[a]
		Smoothness	in/mile	m/km
HMA		Longitudinal cracking	ft/mile	m/km
		Alligator cracking	%/total lane area	m^2/km
		Thermal (Transverse) cracking	ft/mi	m^2/km
		Rutting	in	millimeter
		Smoothness	in/mile	m/km

a. N/A = Not Available

ASSESSMENT OF PAVEMENT CONDITION USING IOWA DOT PMIS

Most of the historical input variables including existing distress information for MEPDG rehabilitation design and analysis are not available in the Iowa DOT PMIS. The most essential information including material properties also are not available in Iowa DOT PIMS. Within the limited research time and scope, it is not possible to collect this information from the field as it would require a well-planned and detailed historic survey over many years to collect this information. However, some historical performance measures are available from 1992 in the Iowa DOT PMIS which could be compared with the MEPDG performance measures.

Representative pavement sites across Iowa were selected in consultation with Iowa DOT engineers to assess historical pavement condition. Criteria for the study sections are listed below.

- Different pavement types (flexible, rigid, and composite)
- Different geographical locations
- Different traffic levels

Five of HMA pavement sections and five of JPCP sections were selected under flexible and rigid pavement categories. Three pavement sites were selected for each of HMA over JPCP and HMA over HMA pavements under composite pavement category. Table 17 summarizes the selected pavement sections. Among the selected pavements sections, US 18 in Clayton was originally constructed as JPCP at 1967 and overlaid with HMA at 1992. After then, this section was again resurfaced with HMA at 2006. However, this study did not consider the pavement conditions after HMA resurfacing at 2006 to avoid irregularity of pavement performance data.

Table 17. Summary of selected pavement sites

Type		Route	Dir.	County	Begin post	End post	Construct -ion year	Resurface year	AADTT[a]
Flexible (HMA)		US218	1	Bremer	198.95	202.57	1998	N/A[b]	349
		US30	1	Carroll	69.94	80.46	1998	N/A	562
		US61	1	Lee	25.40	30.32	1993	N/A	697
		US18	1	Kossuth	119.61	130.08	1994	N/A	208
		IA141	2	Dallas	137.60	139.27	1997	N/A	647
Rigid (JPCP)		US65	1	Polk	82.40	83.10	1994	N/A	472
		US75	2	Woodbury	96.53	99.93	2001	N/A	330
		I80	1	Cedar	275.34	278.10	1991	N/A	7,525
		US151	2	Linn	40.04	45.14	1992	N/A	496
		US30	2	Story	151.92	158.80	1992	N/A	886
Com po- site	HMA over JPCP	IA9	1	240.44	241.48	241. 48	1992	1973	510
		US18[c]	1	285.82	295.74	295. 74	1992	1967	555
		US65	1	59.74	69.16	69. 16	1991	1972	736
	HMA over HMA	US18	1	273.05	274.96	274. 96	1991	1977	2,150
		US59	1	69.73	70.63	70. 63	1993	1970	3,430
		IA76	1	19.78	24.82	24. 82	1994	1964	1,340

a. Average Annual Daily Truck Traffic / b. N/A = Not Available/c. Resurfaced again with HMA at 2006

Available historical pavement distress information for each selected pavement site was retrieved from the Iowa DOT PMIS. Figures 1 to 5 present historical HMA pavement distress information including longitudinal cracking, alligator cracking, thermal (transverse) cracking, rutting and smoothness. Figures 6 to 8 present historical PCC pavement distress information including transverse cracking, faulting and smoothness. Figures 9 to 13 present historical composite pavement distress information including longitudinal cracking, alligator cracking, thermal (transverse) cracking, rutting and smoothness.

In general, the distresses in most of the selected pavement sites increase with age as expected. However, some of distress quantities in some of selected pavement sites appear to decrease with time (see Figure 4) or increase then drop back down (see Figure 6). Similar behaviors have been also observed by recent studies of Wisconsin DOT (Kang, 2007) and Washington DOT (Li, 2009). This behavior may be related to some repair activities performed on these pavements to alleviate serious distresses which are not clearly identified in the Iowa DOT PIMS. Thus, it is recommended that the Iowa DOT PMIS should be updated to provide detailed information related to repair activities for distresses such as the type and time of repair as well as the distress measurements before and after repair.

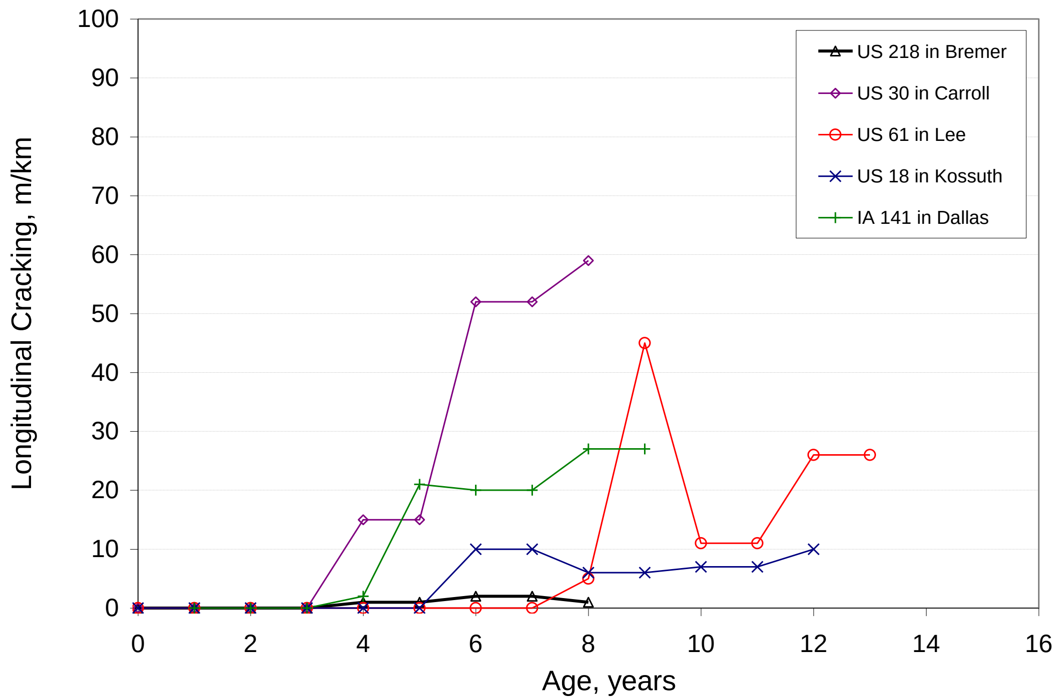

Figure 1. Longitudinal cracking on HMA pavements

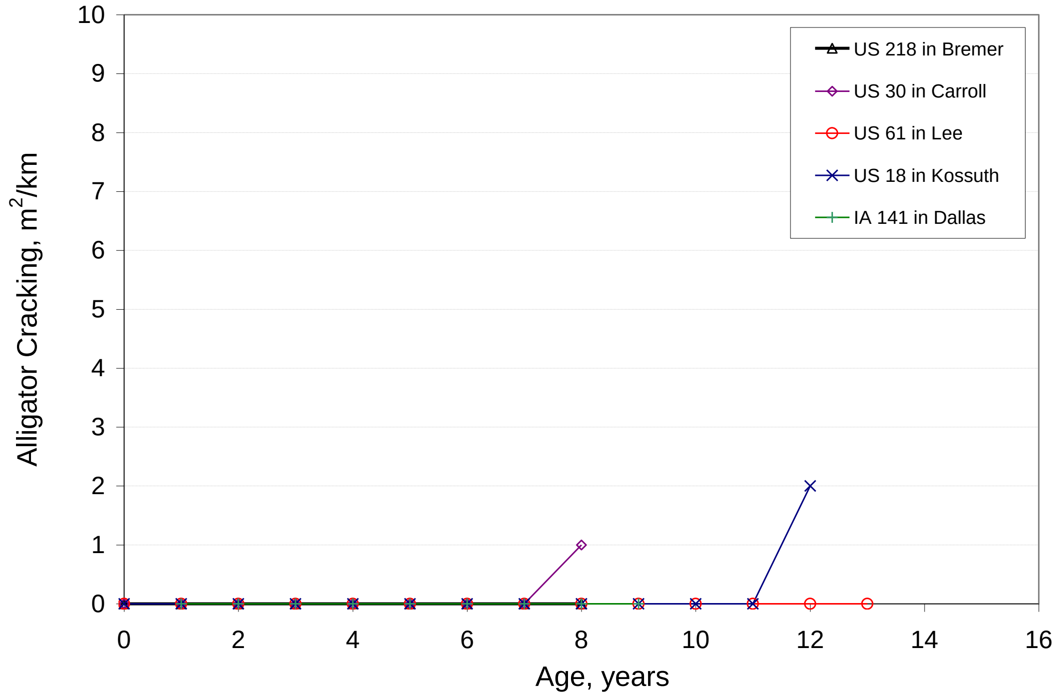

Figure 2. Alligator cracking on HMA pavements

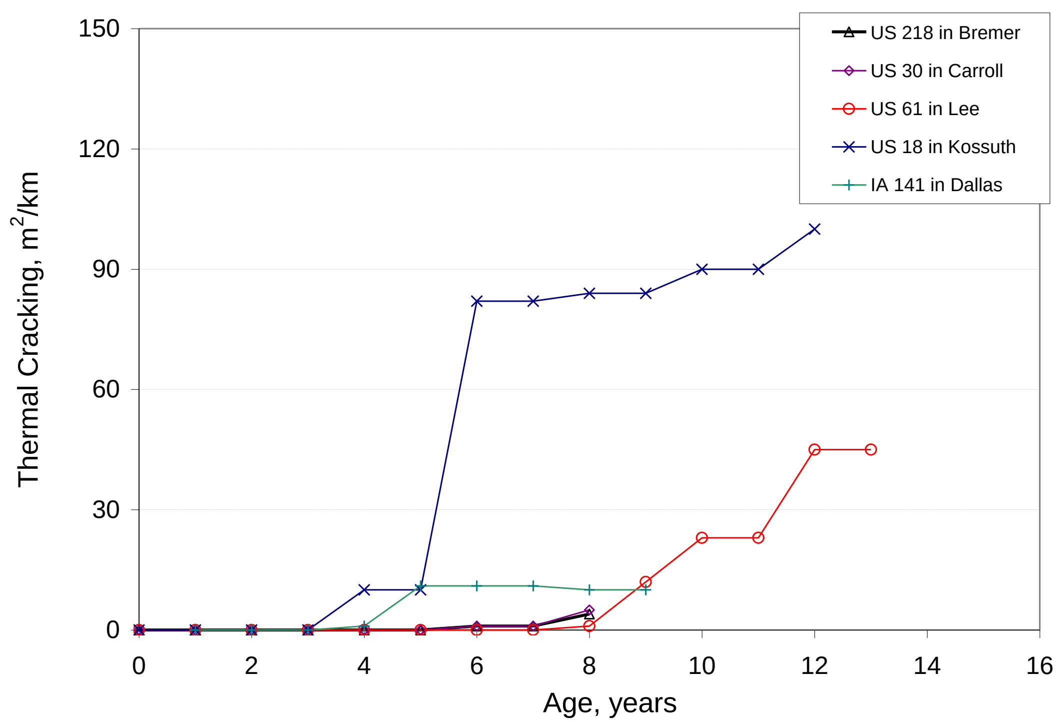

Figure 3. Thermal cracking on HMA pavements

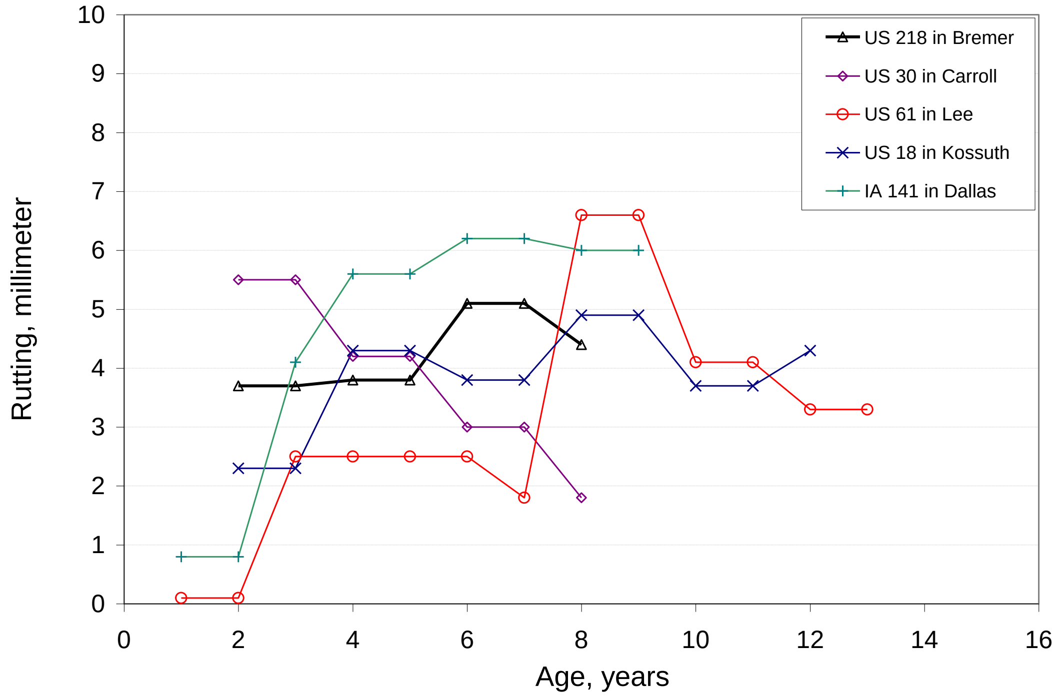

Figure 4. Rutting on HMA pavements

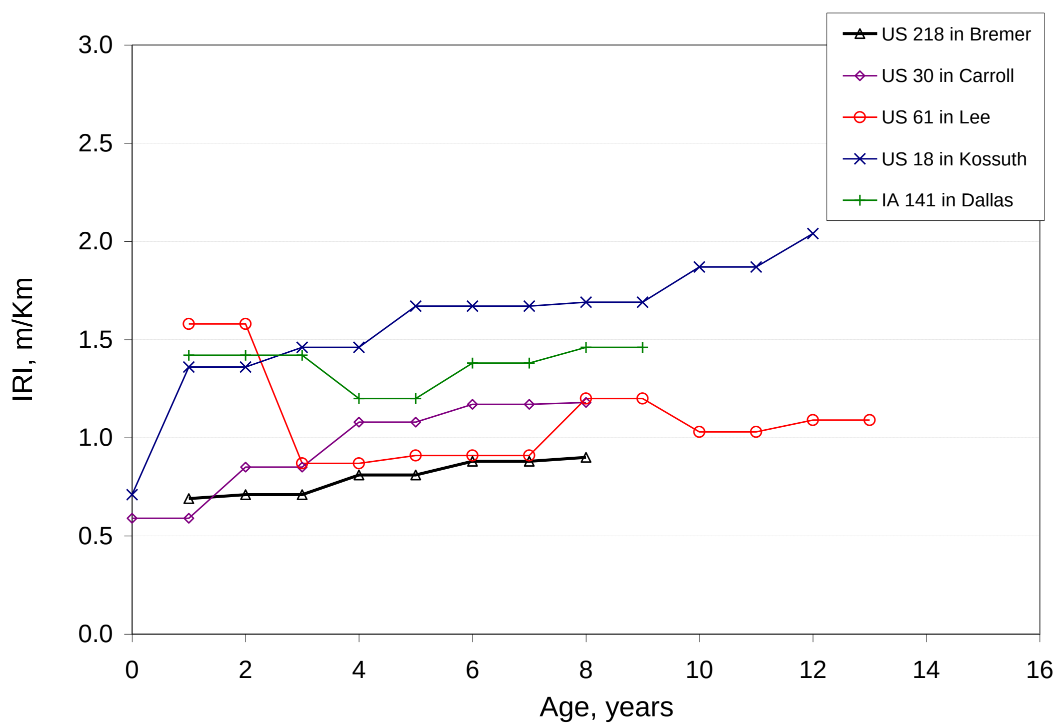

Figure 5. Smoothness (IRI) on HMA pavements

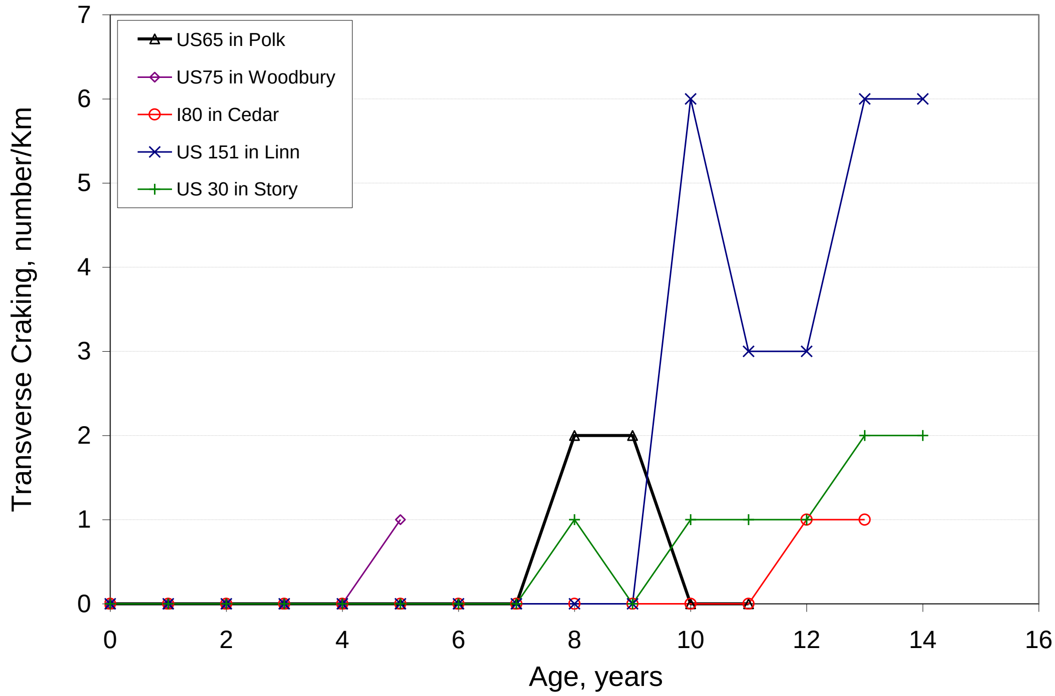

Figure 6. Transverse cracking on JPCPs

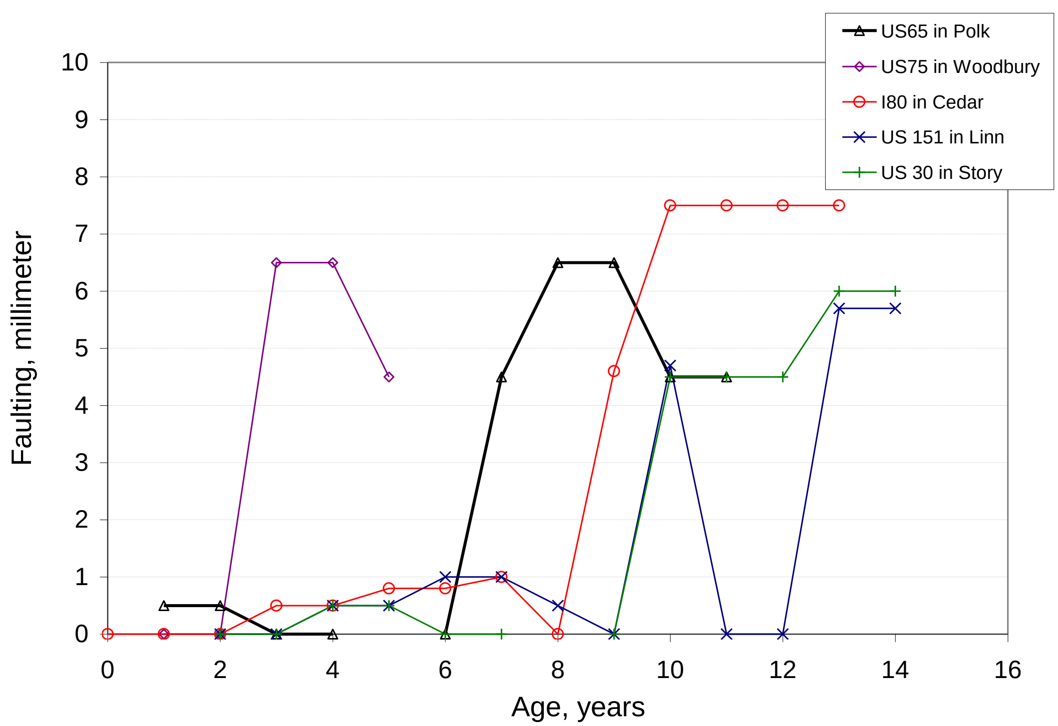

Figure 7. Faulting on JPCPs

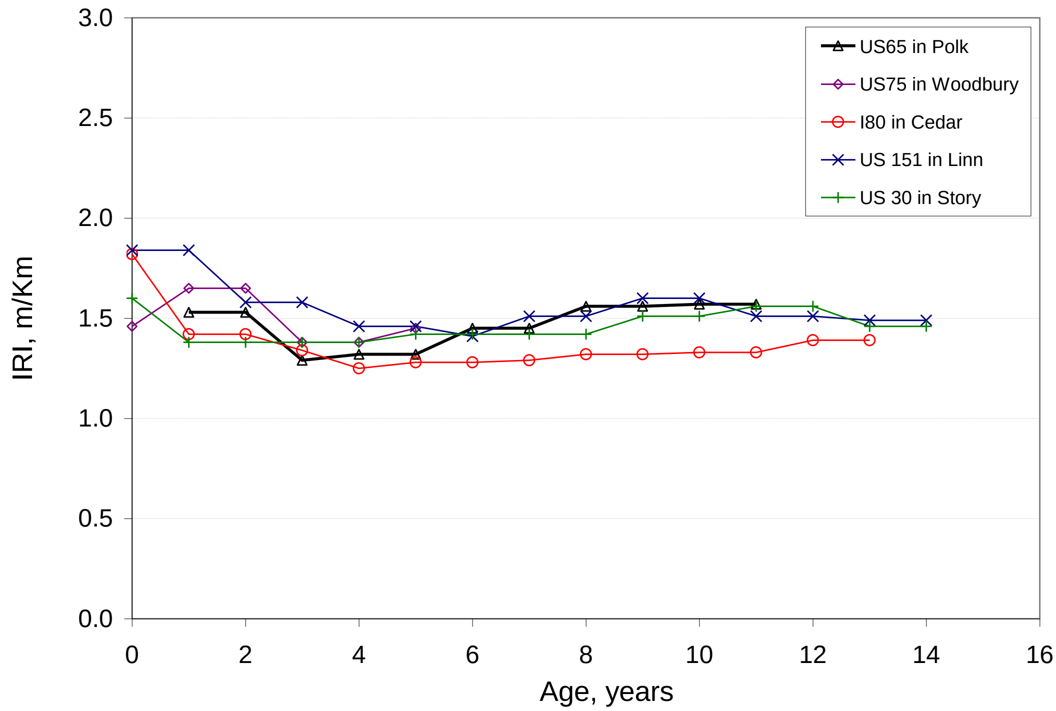

Figure 8. Smoothness (IRI) on JPCPs

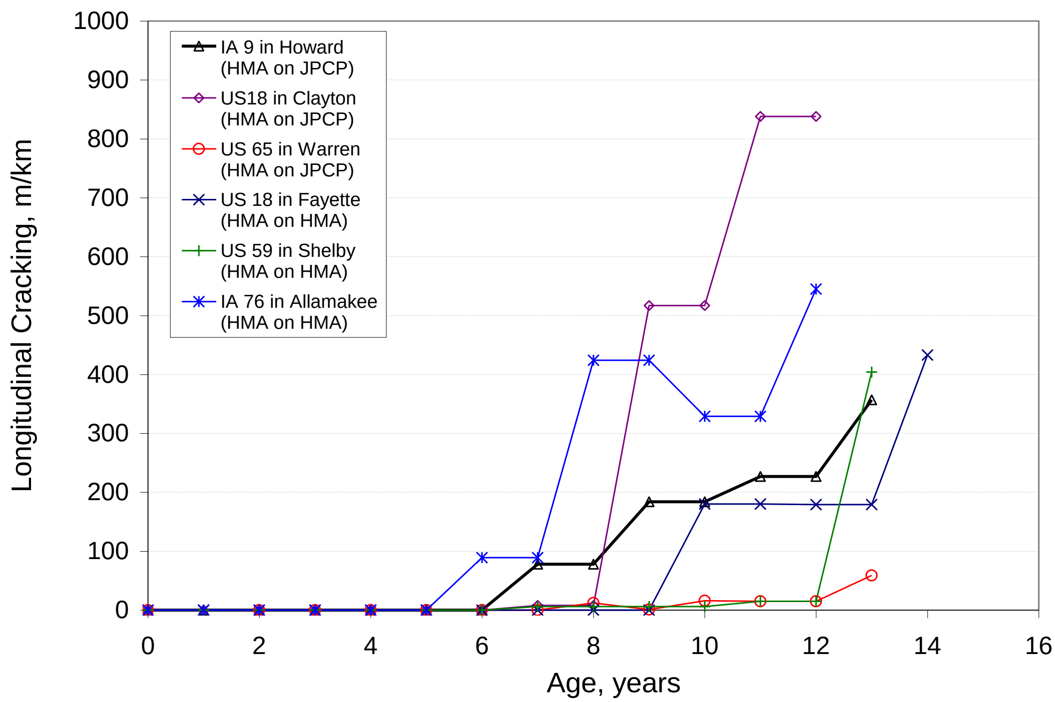

Figure 9. Longitudinal cracking on composite pavements

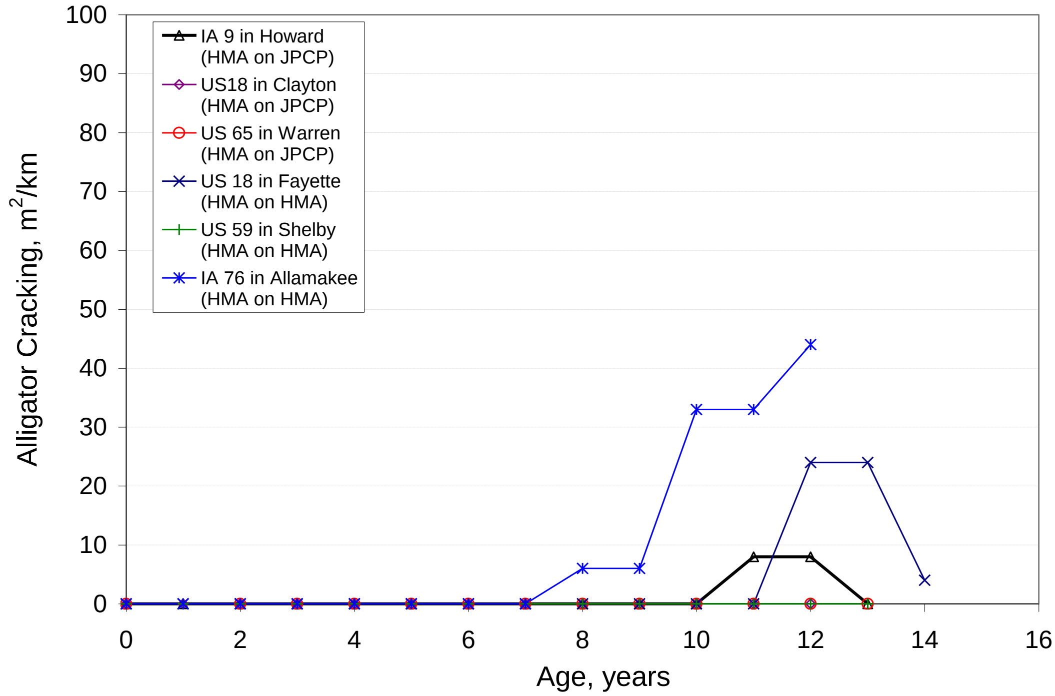

Figure 10. Alligator cracking on composite pavements

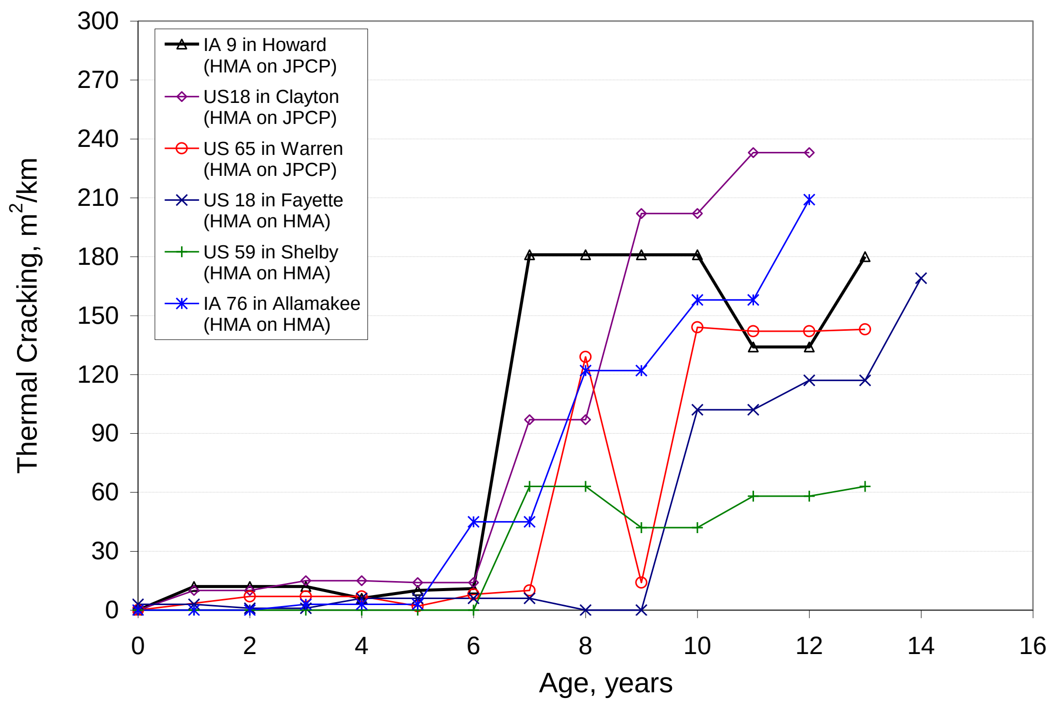

Figure 11. Thermal cracking on composite pavements

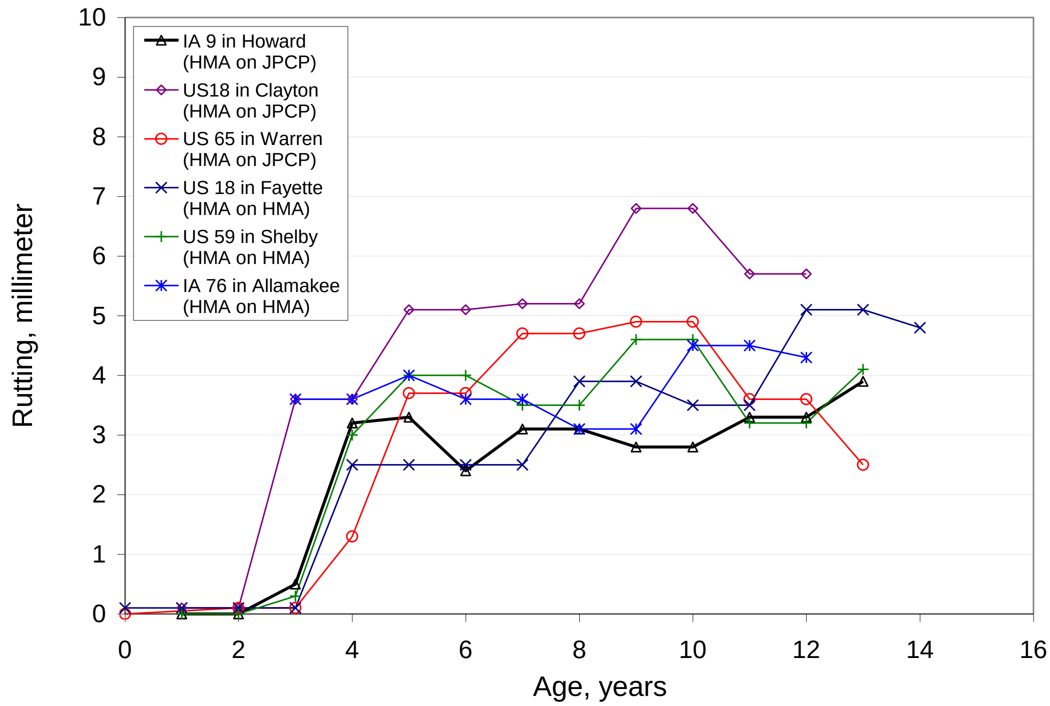

Figure 12. Rutting on composite pavements

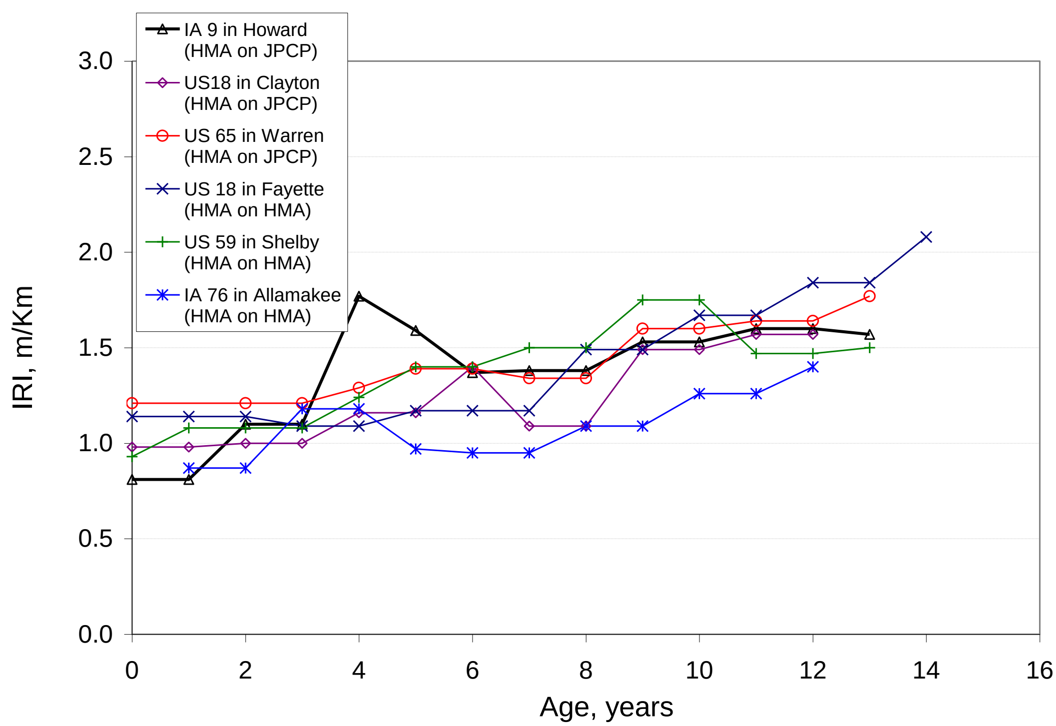

Figure 13. Smoothness (IRI) on composite pavements

SUMMARY AND RECOMMENDATIONS

The primary objective of this study is to systematically evaluate the Iowa DOT's existing PMIS with respect to the input information available for Mechanistic-Empirical Pavement Design Guide (MEPDG) rehabilitation analysis and design. To accomplish this objective, all of available PMIS data, from 1992 to 2006, for all interstate and primary roads in Iowa were retrieved from the Iowa DOT PMIS. The retrieved Iowa DOT PMIS databases were compared and evaluated with respect to the input requirements and outputs for the latest version of the MEPDG software (version 1.0). Based on this, the following findings and recommendations were made for updating the PMIS to facilitate the implementation of MEPDG.

Summary of findings

- Based on literature review, only few studies have been reported so far focusing on detailed data collection procedure and evaluation of the existing pavement condition information for conducting MEPDG rehabilitation analysis and design.
- Only 4 among 9 input parameters for MEPDG HMA rehabilitation design are available in the current Iowa DOT PMIS.
- Only 3 among 7 input parameters for MEPDG PCC rehabilitation design are available in the current Iowa DOT PMIS.
- The detailed material property inputs (e.g., subgrade resilient modulus, HMA dynamic modulus, etc.) which are required for both new and rehabilitation design in MEPDG are not available in the Iowa DOT PMIS.
- Most of the MEPDG performance measures are available in the Iowa DOT PMIS However, three CRCP performance measures including punch-out, maximum crack width and minimum crack LTE are not available in the Iowa DOT PMIS.
- Measurement unit for JPCP transverse cracking in the Iowa DOT PMIS is different from those predicted by MEPDG.
- Measurement units for HMA pavement alligator and thermal (transverse) cracking in the Iowa DOT PMIS are different from those predicted by MEPDG.
- Pavement distress information before 1992 is not available in the Iowa DOT PMIS.
- Detailed information related to pavement distress repair activities are not recorded in the Iowa DOT PMIS.

Recommendations

- The Iowa DOT PMIS should be updated to include the identified unavailable parameters including detailed material properties, existing distress condition for rehabilitation, and detailed distress repair activities such as the type and time of repair as well as the distress measurements before and after repair.
- MEPDG input material properties for rehabilitation design in Iowa should be selected in accordance with MEPDG recommendations (Tables 9 to 15) as well as availability of local resources.

- Measurement units of distress survey results in the Iowa DOT PMIS should be revised to correspond to those of MEPDG performance predictions.

REFERENCES

Loulizi, A., Flintsch, G. W., and McGhee, K. 2007. Determination of the in-place hot-mix asphalt layer modulus for rehabilitation projects using a mechanistic-empirical procedure. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2037: 53-62.

AASHTO. 1993. *AASHTO Guide for Design of Pavement Structures—1993*, Washington, DC.

Applied Pavement Technology, Inc. 2001. *HMA Pavement Evaluation and Rehabilitation—Participant's Workbook*, NHI Course No. 131063. Washington, DC: National Highway Institute.

Ceylan, H., Gopalakrishnan, K., and Coree, B. 2006. A Strategic plan for implementing the mechanistic-empirical pavement design guide in Iowa, CD-ROM. *Presentation at the 2006 Annual Meeting of the Transportation Research Board*, National Research Council, Washington, D. C.

Darter, M. I., Titus-Glover, L., and Mallela, J. 2005. Concrete overlay design of flexible pavement using the NCHRP 1-37A design guide; a case study. *Proceedings of 8th International Conference on Concrete Pavements*, Colorado Springs.

FHWA. 2009. *Design Guide Implementation Team*, http://www. fhwa. dot. gov/pavement/dgit/, assessed by January, 2009.

Federal Aviation Administration. 2004. *Use of Non-destructive Testing in Evaluation of Airport Pavements*, Advisory Circular, 150/5370-11A.

Galal, K. E. and Chehab, G. R. 2005. Implementing the 2002 m-e design procedure using a HMA rehabilitated pavement section in Indiana. *Transportation Research Record: Journal of the Transportation Research Board*, No. 1919: 121-133.

Hall, K. D. and Beam, S. R. 2005. Estimation of sensitivity of design input variables for rigid pavement analysis using mechanistic-empirical design guide. *Transportation Research Record: Journal of the Transportation Research Board*, No. 1919: 65-73.

Kang, M., Adams, T. M., and Bahia, H. 2007. *Development of a Regional Pavement Performance Database of the AASHTO Mechanistic-Empirical Pavement Design Guide: Part 2: Validations and Local Calibration*. MRUTC 07-01. Wisconsin: Midwest Regional University Transportation Center, University of Wisconsin-Madison.

Li, J., Pierce, L. M., and Uhlmeyer, J. S. 2009. Calibration and implementation of flexible pavement portion of mechanistic-empirical pavement design guide for Washington State Department of Transportation, DVD. *Presentation at the 2009 Annual Meeting of the Transportation Research Board*, National Research Council, Washington, D. C.

Nantung, T., Chehab, G., Newbolds, S., Galal, K., Li, S., and Kim, D. H. 2005. Implementation initiatives of the mechanistic-empirical pavement design guides in Indiana. *Transportation Research Record: Journal of the Transportation Research Board*, No. 1919: 142-151.

NCHRP. 2004. *Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures.* www. trb. org/mepdg. Washington, DC: National Cooperative Highway Research Program, Transportation Research Board.

NCHRP. 2006. *Independent Review of the Mechanistic-Empirical Pavement Design Guide and Software*. Research Results Digest 307. Washington, DC: National Cooperative Highway Research Program, Transportation Research Board.

Maher, A., Gucunski, N., and Bennert, T. 2005. *Implementation of Mechanistic Pavement Design: Field and Laboratory Implementation*. ELF-RU7072. New Jersey: Center for Advanced Infrastructure and Transportation (CAIT), Rutgers, the State University of New Jersey.
Rodezno, M. C., Kaloush, K. E., and Way, G. B. 2005. Assessment of distress in conventional hot-mix asphalt and asphalt-rubber overlays on portland cement concrete pavements: using the new guide to mechanistic-empirical design of pavement structures. *Transportation Research Record: Journal of the Transportation Research Board*, No. 1929: 20-27.
Strategic Highway Research Program (SHRP). 1993. *Distress Identification Manual for Long Term Pavement Performance Project*, Publication No. SHRP–P-338, Washington, DC: Strategic Highway Research Program,
Shahin, M. Y. 1994. *Pavement Management for Airports, Roads and Parking Lots*. Germany: Springer.
TRB. 2009. *NCHRP Projects*. http://www. trb. org/CRP/NCHRP/NCHRPProjects. asp, assessed by January, 2009.
Uzan, J., Freeman, T. J., and Cleveland, G. S. 2005. Strategic plan of the Texas department of transportation for implementing NCHRP 1-37A pavement design guide. *Transportation Research Record: Journal of the Transportation Research Board*, No. 1919: 152-159.