CIVIL ENGINEERING STUDIES
Illinois Center for Transportation Series No. 14-012
UILU-ENG-2014-2012
ISSN: 0197-9191

MECHANISTIC-EMPIRICAL DESIGN, IMPLEMENTATION, AND MONITORING FOR FLEXIBLE PAVEMENTS: A PROJECT SUMMARY

Prepared By
Marshall R. Thompson
Imad Al-Qadi
University of Illinois at Urbana-Champaign

Research Report No. FHWA-ICT-14-012

A Project Activity Summary of
ICT-R27-060
Mechanistic-Empirical Implementation and Monitoring for Flexible Pavements

May 2014

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-ICT-14-012		

4. Title and Subtitle	5. Report Date
Mechanistic-Empirical Design, Implementation, and Monitoring for Flexible Pavements: A Project Summary	May 2014
	6. Performing Organization Code
7. Author(s) Marshall R. Thompson and Imad Al-Qadi	8. Performing Organization Report No. ICT-14-012 UILU-ENG-2014-2012
9. Performing Organization Name and Address Illinois Center for Transportation Department of Civil and Environmental Engineering University of Illinois at Urbana-Champaign 205 N. Mathews, MC-250 Urbana, IL 61801	10. Work Unit No. (TRAIS) 11. Contract or Grant No. R27-060
12. Sponsoring Agency Name and Address Illinois Department of Transportation Bureau of Materials and Physical Research 126 E. Ash St. Springfield, IL 62704	13. Type of Report and Period Covered 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This document is a summary of tasks performed for Project ICT-R27-060.

Mechanistic-empirical (M-E)–based flexible pavement design concepts and procedures were developed in previous Illinois Cooperative Highway Research Program projects (IHR-510, IHR-524, and ICT- R28) and have been implemented by the Illinois Department of Transportation (IDOT). IDOT continues to support a variety of M-E flexible pavement analysis, design, implementation, and monitoring activities. The objective of Project ICT-R27-060 was for University of Illinois staff to continue to provide technical support and cooperate with IDOT in these activities.

The cost savings (and probably reduced user delay time) from such designs will benefit IDOT, local roads agencies, and the travelling public.

17. Key Words	18. Distribution Statement
Pavement; flexible pavement; mechanistic-empirical pavement design	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	6	N/A

Form DOT F 1700.7 (8-72)Reproduction of completed page authorized

ACKNOWLEDGMENT, DISCLAIMER, MANUFACTURERS' NAMES

This publication is a summary of project tasks for ICT-27-060, **Mechanistic-Empirical Implementation and Monitoring for Flexible Pavements**. ICT-R27-060 was conducted in cooperation with the Illinois Center for Transportation; the Illinois Department of Transportation (IDOT), Division of Highways; and the U.S. Department of Transportation, Federal Highway Administration.

Members of the Technical Review Panel (TRP) were the following:

Charles Wienrank (Chair), Illinois Department of Transportation

Amy Schutzbach, Illinois Department of Transportation

David Lippert, Illinois Department of Transportation

Marvin Traylor, Illinois Asphalt Pavement Association

Paul Niedernhofer, Illinois Department of Transportation

LaDonna Rowden, Illinois Department of Transportation

Joseph Vespa, Illinois Department of Transportation

Hal Wakefield, Federal Highway Administration, Illinois Division

Kevin Burke III, Illinois Department of Transportation

INTRODUCTION

Mechanistic-empirical (M-E)–based flexible pavement design concepts and procedures were developed in previous Illinois Cooperative Highway Research Program projects (IHR-510, IHR-524, and ICT- R28) and have been implemented by the Illinois Department of Transportation (IDOT). IDOT continues to support a variety of M-E flexible pavement analysis, design, implementation, and monitoring activities. Many reports and white papers have been prepared for the various projects and provided to IDOT. The objective of Project ICT-R27-060 was for University of Illinois staff to continue to provide technical support and cooperate with IDOT in these activities. R27-060 included the following tasks:

Task 1: Cooperate in the review and revision of the Bureau of Local Roads and Streets (BLRS) Pavement Design Manual.

Task 2: Review IDOT hot-mix asphalt (HMA) overlay design procedures and provide inputs for modification.

Task 3: Provide (on an as-requested/needed basis) support concerning full-depth HMA design and other special topics.

Task 4: Monitor/evaluate new/developing technology concerning M-E pavement analysis and design.

Task 5: Evaluate the impact of using recycled materials on M-E pavement design and pavement performance.

PROJECT ACCOMPLISHMENTS

Major project accomplishments for the various tasks are summarized below. Project inputs concerning the tasks were provided to IDOT via white papers, TRP meeting presentations, e-mail memoranda, and telephone conversations.

TASK 1: COOPERATE IN THE REVIEW AND REVISION OF THE BUREAU OF LOCAL ROADS AND STREET (BLRS) PAVEMENT DESIGN MANUAL

Marshall Thompson (the project's principal investigator) reviewed various versions of the draft versions of the revised BLRS manual (Chapter 44, Pavement Design) and provided review comments and inputs concerning design time/hot-mix asphalt (HMA) temperature, HMA modulus–temperature relationships, a revised HMA fatigue algorithm, design reliability/traffic multiplier factors, and maximum HMA thickness. At this time, all issues requiring project input have been satisfactorily addressed by Thompson.

TASK 2: REVIEW IDOT HOT-MIX ASPHALT OVERLAY DESIGN PROCEDURES AND PROVIDE INPUTS FOR MODIFICATION

The previously developed DEFPOL (Design of Flexible Pavement Overlays) computer program was modified (can now accommodate variable "k" and "n" HMA fatigue algorithm parameters) and presented to the TRP for review. The user-friendly program incorporates the same design concepts used in IDOT's full-depth HMA and conventional flexible pavement (CFP) design procedures.

IDOT policy permits the use of the Asphalt Institute's HMA overlay design procedure presented in AI MS-17. The AI deflection- life chart was revised to reflect the use of falling-weight deflectometer (FWD) deflections. The MS-17 thicknesses were compared with those that would be required if the current IDOT HMA fatigue algorithm was used. The factor of safety for the AI procedure (AI design traffic factor/IDOT design traffic factor) is about 3.6. It was indicated that this factor is excessive for low-volume roads (<0.5 millions of equivalent single axle loads, or MESALs). It was suggested that the factor should be lowered (perhaps to ~2) to be consistent with the BLRS's proposed CFP policy (traffic multiplier of 2 for <0.5 MESALs).

TASK 3: PROVIDE (ON AN AS-REQUESTED/NEEDED BASIS) SUPPORT CONCERNING FULL-DEPTH HMA DESIGN AND OTHER SPECIAL TOPICS

IDOT's draft recommendations on temporary pavements were reviewed and analyzed, and feedback comments were provided to IDOT.

HMA fatigue analyses were conducted to establish maximum HMA thicknesses for full-depth HMA and HMA overlays of rubblized Portland cement concrete pavement (PCCP). The maximum values were incorporated into Chapter 54 (Pavement Design) of the Bureau of Design and Environment (BDE) Manual.

During a plan review of a 2013 rubblization project on I-55 north of I-70, Thompson noted that a granular fill layer was to be constructed on the surface of the rubblized PCCP layer to achieve grade requirements. Current IDOT policy does not permit this practice. The project was modified to eliminate the granular layer.

During the project, Thompson visited many rubblization project sites (new and old) to observe current construction practices and visually monitor HMA overlay performance. The Edgewood, Illinois, project on I-57 was constructed in 1996 (8-inch HMA overlay and a limited section with a 6-inch HMA overlay).

In 2011, the project was lightly milled and a stone matric asphalt (SMA) overlay constructed. During a project site visit, the milled surface was inspected. Both HMA overlays were in excellent shape. Charles Wienrank (IDOT) indicated that the HMA overlays had accommodated about 18.5 MESALs. Another project of particular interest (in summer 2013) was a study of the variable HMA overlay thicknesses (9, 10, and 11 inches) on I-70 (Greenup-Casey). IDOT collected FWD data, which were analyzed by the principal investigator. The project (constructed in 1997) is performing very well. IDOT conducted FWD testing (HMA temperature at 3 inches = 99°F) in the 1997 sections prior to the milling operation. The data were analyzed, and the estimated HMA strains were as follows:

- 9-inch HMA overlay: 64 microstrain
- 10-inch HMA overlay: 69 microstrain
- 11-inch HMA overlay: 61 microstrain

These values indicate that the sections display significant fatigue resistance. According to Charles Wienrank, the sections have accumulated approximately 32 MESALs through the summer of 2013. There were no areas that showed HMA fatigue distress.

Per IDOT's request, analyses were conducted to evaluate (specifically for the 2013 I-39 project north of Normal, Illinois) the use of stage construction for HMA overlay of rubblized PCCPs. An initial HMA overlay thickness of 8 inches was programmed. The analyses confirmed that stage construction was a viable process.

Several unusual flexible pavement design problems were reviewed for the Bureau of Materials and Physical Research (BMPR) and BLRS, and comments were forwarded to them.

The previous IDOT MTD specification limited surface contact pressures to 20 psi (this restriction did not apply to the initial HMA lift). Per IDOT request, analyses were conducted for various wheeled and tracked material transfer devices (MTDs)s. No wheeled MTD can meet the 20 psi requirement. Subsequently, IDOT requested ILLI-PAVE analyses for tracked MTDs with 25 psi track pressures. The results indicated that the increase from 20 psi (current limit) to 25 psi was tolerable. Review comments on a revised MTD specification were provided to IDOT.

TASK 4: MONITOR/EVALUATE NEW/DEVELOPING TECHNOLOGY CONCERNING M-E PAVEMENT ANALYSIS AND DESIGN

NCHRP Project 9-44A results (published in NCHRP Report 762, Laboratory Validation of an Endurance Limit for Asphalt Pavements, 2013) were reviewed. The project demonstrated that the HMA fatigue endurance limit (FEL) was not unique but varied with HMA modulus (it decreases as the modulus increases) and rest period (it increases as the rest period increases up to about 5 seconds). The IDOT HMA FEL is 70 microstrain. Analyses of some typical Illinois full-depth HMA pavement sections indicated that use of the current IDOT HMA FEL is still appropriate.

Thompson recommended that IDOT participate in the FHWA Travel Speed Deflectometer (TSD) Pooled Fund Study. It was suggested TSD deflection and deflection variability data would be useful in refining the thickness design procedures for HMA full-depth and HMA overlay of rubblized PCCP. In an early (pre-IDOT Pooled Fund commitment) contact with Jorgen Kraup of Greenwood Engineering (the current TSD operator), Thompson was informed that IDOT's area under pavement profile (AUPP) deflection basin parameter could easily be incorporated into the TSD data file. AUPP can be used to reliably estimate HMA strain. IDOT opted to participate (two separate testing periods) in the FHWA TSD study. Initial TSD testing will be conducted in early summer 2014. Thompson volunteered to cooperate with IDOT in analyzing the TSD data and evaluating the potential use of TSD data.

TASK 5: EVALUATE THE IMPACT OF USING RECYCLED MATERIALS ON M-E PAVEMENT DESIGN AND PAVEMENT PERFORMANCE

During the early part of the project, Thompson participated in the BLRS CIRWAP (Cold In-Place Recycling with Asphalt Products) Working Group. Results from completed ICT Project R27-12 (Cold In-Place Recycling and Full-Depth Recycling with Asphalt Products, for which Thompson was the principal investigator) were very helpful in the effort. The working group developed relevant mix design and construction specifications. Good progress was achieved, and CIRWAP policies and specifications were published by BLRS on April 1, 2012. Thompson continues to review and evaluate CIRWAP research and development activities and to informally monitor CIRWAP project construction and performance.

In-place recycling of existing pavement sections with cement has become a common process in Illinois, particularly with LRS agencies. IDOT's AASHTO structural number (SN) procedure and layer coefficients for high-strength stabilized base (HSSB) materials were reviewed. Thicknesses established per IDOT's AASHTO SN approach do not compare favorably with field performance. Thompson visited several Jasper County cement-treated (generally 9% cement) base projects. The sections were 8 inches thick and had A-2 surface treatments. The design traffic for the projects ranged from about 9 to 51 kip-equivalent single axle loads (KESALs). The oldest project was about eight years. The sections (although thin, are based on IDOT's AASHTO SN procedure) are providing excellent performance. Typical of cement-treated bases, all have shrinkage cracking of various spacings (the cracks were narrow). Similar observations were noted for a cement-stabilized base section in Edgar County (9-inch cement-stabilized base, 5.5% PC; A-2 surface treatment; 2009 IDOT letting).

Subsequently, current approaches for the analysis and design of HSSB pavements were reviewed. Particular emphasis was placed on HSSB fatigue algorithms. Current approaches based on previously developed ILLI-PAVE algorithms and HSSB fatigue algorithms appear to be very conservative, based on preliminary analyses of several recent soil-cement projects (particularly the Jasper County projects). AUSTROADS has conducted extensive studies on HSSB fatigue; their publications and other related literature continue to be reviewed. It is apparent that there is no consensus concerning HSSB fatigue algorithms (some are stress/stress ratio–based, and some are strain-based). Meyerhof's ultimate load theory also shows good potential for explaining observed field performance.

A summary of the HSSB analysis/design activities was presented at the October 2013 TRP meeting for this project. Thompson has developed an HSSB thickness design approach that more realistically predicts the performance observed for the Jasper and Edgar County projects. Thompson has proposed to BMPR that FWD testing (and hopefully some coring operations) be conducted on some previous full-depth reclamation (FDR) with cement projects. Previously constructed projects in Jasper County and Edgar County are of particular interest. These data would be very helpful in validating/calibrating the thickness design approaches developed in the project.

Thompson continues to informally monitor cement-stabilized base projects. It was noted in the April IDOT letting that Jasper County will construct an FDR with cement project (8-inch; 8% PC; A-2 surface treatment) in summer 2014.

Thompson participated in the BLRS FDR with the Portland Cement Working Group. Current IDOT cement-stabilization specifications/policies are in some instances in apparent conflict. Cured compressive strength requirements are not consistently applied. Thompson provided input to BMPR concerning the 500 psi compressive strength requirement for cement-treated base. A similar issue was considered for the 2012 District 5 Philo Road project in Urbana, IL. Thompson provided input to IDOT (District 5 – BLRS and BMPR) and the City of Urbana concerning mixture design and strength issues on the Philo Road project. Ultimately, the project was modified to accommodate the use of cement-modified subgrade and a full-depth HMA surface. A presentation on soil–cement fundamentals was made at the December 18, 2012, meeting at District 3 (Ottawa). The presentation included freeze–thaw evaluation concepts (previously developed by Barry Dempsey and Marshall Thompson in an ICHRP project) based on vacuum saturation strength of lab-cured specimens. Thompson reviewed the December 2012 draft specification and submitted comments to Kevin Burke BLRS. Thompson participated in the subsequent working group meeting. The working group has made some progress, but additional work is needed to finish the development of improved mixture design procedures, construction specifications, and thickness design procedures. The working group has not met since February 2013. The increased use of in-place stabilization with cement warrants resumption of working group activities.

Throughout the project, Thompson reviewed relevant literature concerning in-place recycling technology.

PROJECT OUTCOME/DELIVERABLES

Project ICT R27-060 has provided inputs pertinent to providing improved mechanistic-empirical flexible pavement design procedures for use by IDOT's Bureau of Design and Environment and Bureau of Local Roads and Streets.

Project support (provided to IDOT on an as-requested/needed basis) related to special topics provided significant inputs to IDOT and contributed to its consideration of several issues. Project activities related to in-place recycling (particularly asphalt products and cement) are considered very important, and significant progress has been achieved in advancing in-place recycling technology. Thompson's continued informal monitoring activities for HMA overlays of rubblized PCCP and in-place recycling are considered very helpful to the success of the project.

To maximize the impact of M-E flexible pavement design procedures, they should reflect current technology (as appropriate for IDOT conditions). Project ICT R27-060 contributed to IDOT's use of best-demonstrated available technology (BDAT), which continues to evolve in many M-E areas of interest. Considerable cost savings and better pavement performance can be realized with improved, more accurate M-E pavement design procedures. The cost savings (and probably reduced user delay time) from such designs will benefit IDOT, local roads agencies, and the travelling public.