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Investigation of Warm-Mix Asphalt for Iowa Roadways, Phase II

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Abstract

Phase II of this study further evaluated the performance of plant-produced warm-mix asphalt (WMA) mixes by conducting additional mixture performance tests at a broader range of temperatures, adding additional pavements to the study, comparing virgin and recovered binder properties, performing pavement condition surveys, and comparing survey data with the Mechanistic Empirical Pavement Design Guide (MEPDG) forecast for pavement damage over 20 years of service life. Further objectives detailing curing behavior, quality assurance testing, and hybrid technologies were as follows: * Compare the predicted and observed field performance of existing WMA trials produced in the previous Phase I study to that of hot-mix asphalt (HMA) control sections to determine if Phase I conclusions are translating to the field; * Identify any curing effect (and timing of the effect) of WMA mixtures and binders in the field; * Determine how the field-compacted mixture properties and recovered binder properties of WMA compare to those of HMA over time for technologies common to Iowa; * Identify the protocols for WMA sample preparation for volumetric and performance testing that best simulate field conditions. The findings of this study indicate that WMA additives do show statistical differences in mixture properties in some of the mixes tested. These differences will not always be statistically different from mixture to mixture. Multiple factors, such as WMA additive type, amount of recycled asphalt material, construction conditions, and mixture variability all play a role in determining the extent of which WMA and HMA mixes differ. Other significant findings of this study include effects of curing, aging in recovered binders from HMA and WMA cores, and the influence of recycled asphalt shingles (RAS) used with WMA. These findings will be of interest to owner agencies and contractors utilizing WMA technologies.

Keywords

Asphalt, Asphalt pavements, Hot mix asphalt, Pavements, Performance tests, Recycled materials, Warm mix asphalt, pavement survey, recycled asphalt shingles, HMW, WMA

Disciplines

Civil Engineering

Comments

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IOWA STATE UNIVERSITY
Institute for Transportation

Investigation of Warm Mix Asphalt for Iowa Roadways – Phase II

tech transfer summary

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The mission of the Institute for Transportation (InTrans) at Iowa State University is to develop and implement innovative methods, materials, and technologies for improving transportation efficiency, safety, reliability, and sustainability while improving the learning environment of students, faculty, and staff in transportation-related fields.

This Phase II study incorporates additional testing at a wider range of temperatures, testing of pavement cores, extracted binder tests, and pavement condition surveys of warm mix asphalt mixes located and produced in Iowa.

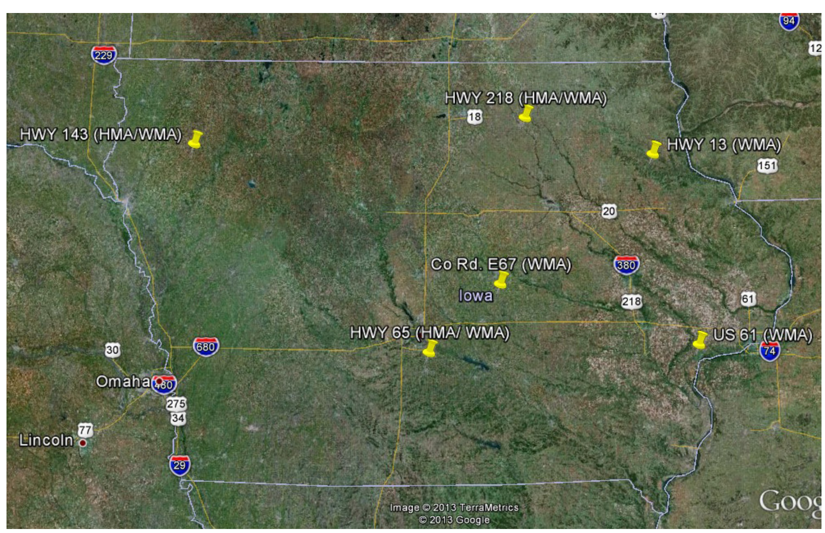
Background

The implementation of warm mix asphalt (WMA) is becoming more widespread with a growing number of contractors utilizing WMA technologies to take advantage of reduced mixing and compaction temperatures, reduced fuel consumption, and improved compactability. WMA technology has demonstrated beneficial economic value as well as environmental value in other parts of the US and Europe.

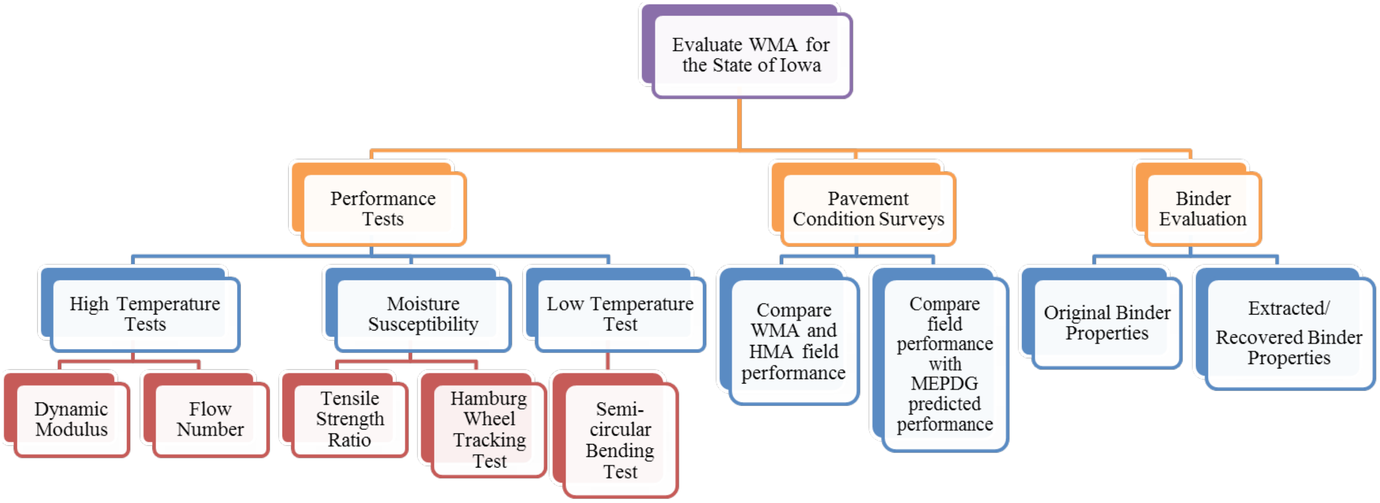
Phase I Research

In 2009, three pavements were constructed with mixes having both hot mix asphalt (HMA) and WMA test sections as part of the Phase I WMA study. Mix was compacted at the construction sites, without reheating, and additional mix was collected to later reheat and compact in the laboratory. Virgin binder, collected from the tank at the asphalt plant, was sampled for further binder analysis during construction.

Phase I testing included indirect tensile strength, dynamic modulus, and flow number testing. Phase I conclusions indicated some differences between the WMA mix properties and HMA properties; however, trends were not present over all the mixes tested. Phase I showed differences between control HMA mixes and WMA mixtures in moisture conditioning and dynamic modulus performance.



Roadway pavement locations for the WMA study (Image ©2013 TerraMetrics ©2013 Google Earth)



Conceptual diagram of Phase II scope and testing plan

Project Objectives

The objective of Phase II of this study was to further evaluate the performance of plant-produced WMA mixtures. Phase II utilizes the information in Phase I to show a broader picture of how WMA additives impact the asphalt pavements.

More specifically, objectives were to detail curing behavior, quality assurance testing, and hybrid technologies, as follows:

- Compare the predicted and observed field performance of existing WMA trials produced in the previous Phase I study to that of HMA control sections to determine if Phase I conclusions are translating to the field
- Identify any curing effect (and timing of the effect) of WMA mixtures and binders in the field
- Determine how the field-compacted mixture properties and recovered binder properties of WMA compare to those of HMA over time for technologies common to Iowa
- Identify protocols for WMA sample preparation for volumetric and performance testing which best simulate field conditions

Research Methodology

Phase II was undertaken to conduct more mixture tests at a broader range of temperatures, add the Hamburg wheel tracking test, add additional pavements to the study, perform pavement condition surveys, and compare pavement condition data with the Mechanistic-Empirical Pavement Design Guide (MEDPG) forecast for pavement damage over the next 20 years.

Additional WMA pavements were constructed in 2010 and added to the WMA study as part of the Phase II project. Phase I and Phase II of the WMA investigation contained 11 total mixes, as shown in the table. All mixes were produced in asphalt plants and used to construct asphalt roadways throughout the state.

For each mix, samples were compacted in a Superpave gyratory compacter on the day of production, reheated, and compacted in the laboratory. In addition to the gyratory-compacted samples, field cores were taken after one or two years of in-service aging.
For each mix, tank binder was collected and tested. Binder was recovered from cores and tested. Dynamic modulus, flow number, semi-circular bending test, indirect tensile strength (TSR), Hamburg wheel tracking tests were performed on all mixes.

A curing study was also performed in the Hamburg on three mixes. Mixture properties were statistically compared and factors within each mix were analyzed by performing an analysis of variance. Binder performance grading was conducted on all mixes included in the study.

Pavement survey data was collected for two years and compared with the MEPDG pavement performance results. Mixture and binder performance data were used to rank mixes and standardized rankings were used to compare overall performance of the mixtures.

Key Findings

All of the different areas of study, together, provide a holistic view of the detectable impact that WMA additives have on HMA pavements.

Based on the mixes tested in this study and the collected data from measured test parameters in this research, the following can be concluded:

- WMA additives do show statistical differences in mixture properties in some of the mixes tested. These differences will not always be statistically different from mixture to mixture. Multiple factors, such as WMA additive type, construction conditions, and mixture variability, all play a role in determining the extent of which WMA and HMA mixes differ.
- Curing time and temperature greatly influence the stripping inflection point in the Hamburg. The lower WMA temperature with curing times below 2 hours did not perform as well as the samples cured and compacted at HMA temperature or for longer curing durations.
- On average, WMA had lower flow numbers when compared with the HMA control unless the reduced stiffness is offset by recycled materials added to the mixture.
- Cores usually performed better in the Hamburg compared to gyratory samples. The shingles in Mix FM7-7 greatly increased the performance of that mixture in the Hamburg. Between HMA and WMA samples, one did not perform consistently better than the other.
- Comparing tensile strength ratio (TSR) and stripping inflection point (SIP) values showed that more mixes fall below a SIP of 10,000 (and 14,000) as compared to a TSR of 0.80.
- Semi-circular bending (SCB) tests at low temperatures did show some good correlations with other measured material properties but the test data is generally too variable to be able to calculate statistical differences at low alpha levels.
- The Sasobit mixture, FM3 WMA, exhibited a significantly lower indirect tensile strength compared with the HMA control.
- The mixes with recycled asphalt shingles (RAS) (5% and 7%) did not perform well in TSR tests.
- RAS had a much greater influence on recovered binder properties than the recycled asphalt pavement (RAP).
- All recovered binders from field cores showed an increase in high temperature by at least 5°C.
- Data from pavement performance show distresses in the field but do not show large differences in performance between HMA and WMA sections.

Pavements included in Phase I and Phase II

Code	Year	Highway	Iowa DOT Project Number	WMA Technology	Mix Type	Binder Grade	RAP	RAS
FM2 (HMA/WMA)	2009	US Hwy 218	NHSX-218-9(129)--3H-34	Evotherm	HMA 10M	64-28	17%	--
FM3 (HMA/WMA)	2009	Iowa Hwy 143	STP-143-1(4)--2C-18	Sasobit	HMA 3M	64-22	20%	--
FM4 (HMA/WMA)	2009	US Hwy 65	STP-065-3(57)--2C-91	Foaming	HMA 3M	64-22	20%	--
FM5	2010	CR E-67	STP-S-C064(110)--5E-64	Evotherm	HMA 300K	64-22	20%	--
FM6	2010	Iowa Hwy 13	MP-013-2(704)59--76-22	Evotherm	HMA 1M	64-22	5%	--
FM7-0	2010	US Hwy 61	HSIPX-061-4(107)--3L-70	Evotherm	HMA 1M	58-28	20%	--
FM7-5	2010	US Hwy 61	HSIPX-061-4(107)--3L-70	Evotherm	HMA 1M	58-28	13%	5%
FM7-7	2010	US Hwy 61	HSIPX-061-4(107)--3L-70	Evotherm	HMA 1M	58-28	6%	7%

Mix Type: M = million and K = thousand equivalent single axle loads (ESALS)
Binder Grade = performance grade (PG)

Implementation Benefits and Readiness

Although beyond the scope of this study, the identified economic value of WMA technology is due to the reduction of plant temperatures by 50 to 100°F, fuel savings, the improved field compaction allowed (reduction in roller coverage), and/or shorter haul distances. The environmental benefits of WMA additives include reduced HMA plant emissions because of the reduced plant production temperatures, as well as reduced worker exposure to fumes during the production/construction process.

Pavement survey location on County Road E-67

Recommendations

- The curing study shows that there are effects of time and temperature for the mixture conditioning. The higher temperature or longer curing durations for a mix consistently showed improved results with Hamburg testing. Using the Hamburg as a standard in Iowa will help to identify WMA practices that may lead to inferior performance.
- The mixture with 7% RAS showed a substantial increase in performance in the Hamburg. Other tests, such as fatigue testing or low temperature tests will compliment a Hamburg test specification.
- Additional warm mixes that use RAS should be studied because the TSR values were very low for the 7% RAS mixture. The reduction may be due to the combination of increased RAS at a low temperature.
- Continuation of the pavement conditioning surveys may help to identify differences in performance between HMA and WMA in the future, but warm mix additives did not appear to influence recovered binder properties after one or two years in the field.
- The TSR value showed no correlation to the SIP measured in a Hamburg test. The Hamburg was generally more selective of mixes; therefore, mixes that have previously passed the TSR minimums will likely need to be reevaluated in the Hamburg for the new SIP specification that replaces the TSR criteria.
- The WMA additives should continue to be used as long as moisture susceptibility and rutting resistance can be shown to be equal to that of HMA pavements.