JANUARY 2017

NCHRP PRACTICE-READY SOLUTIONS FOR

Warm Mix Asphalt

NCHRP NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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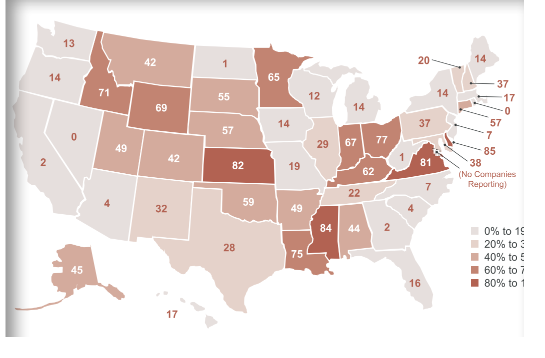

Warm Mix Asphalt: From 0 to 30 Percent in 10 Years

Warm mix asphalt (WMA) is an innovation in pavement construction that has seen widespread implementation in the past decade. It's a true success story—a novel technology backed by solid NCHRP research.

WMA refers to asphalt mixtures produced at temperatures substantially cooler—by as much as 50 degrees Fahrenheit or more in some cases—than typically used in the production of hot mix asphalt (HMA). The goal of WMA is to produce mixtures with similar strength, durability, and performance characteristics as HMA, using substantially reduced production temperatures.

There are important potential environmental and health benefits associated with reduced production temperatures, including lower emissions during production and laydown, lower fuel consumption, and reduced worker exposure to asphalt fumes. Lower production temperatures may also improve pavement performance by reducing binder aging, providing added time for mixture compaction, and allowing improved compaction during cold weather paving.

A variety of technologies are used to produce WMA. These include proprietary chemicals in the form of surfactants, waxes, and foaming agents (typically zeolites) introduced at the terminal or during mix production. Technologies also include generic or proprietary equipment installed on the mix plant to enable asphalt foaming through water injection during mix production.

Perhaps the best proof of WMA as a concept is the extent to which it has been deployed across the United States. The first trials of WMA in the United States were in the early 2000s. By 2014, WMA constituted approximately 30 percent of all asphalt mix placed in the United States, and that percentage continues to grow.

WMA production can be cooler than HMA production by more than 50 degrees Fahrenheit.

Image courtesy of FHWA

Image courtesy of Utah DOT

WHY RESEARCH WMA?

Traditional HMA is a well-understood and time-tested product. Many robust protocols have been developed and verified through NCHRP, including the Superpave mix design method and the methods presented in Mechanistic–Empirical Pavement Design Guide. To ensure that WMA will meet the same high standards as HMA, NCHRP:

- Investigated possible concerns related to **unique aspects of WMA mix design and construction**, such as insufficient rutting resistance and moisture susceptibility.
- Studied **short- and long-term performance** of WMA compared with HMA.
- Established **mix design protocols** for WMA, including basic design guidance to complement HMA design, and design issues unique to WMA, such as foaming.
- Continues to examine **emerging issues**. For example, work on the use of WMA with reclaimed asphalt shingles is in progress, and long-term validation continues for some of the areas noted above.
- Advocates **expanded use** of WMA. NCHRP will encourage wider implementation during a 2017 workshop planned for state transportation agencies.

> "While warm mix asphalt appears to be an obvious winner, road agencies rely on research-based guidance from NCHRP to make informed decisions on every aspect of WMA design and construction."
>
> —Edward Harrigan, Transportation Research Board

Unique WMA Construction Raises Questions

NCHRP Project 09-49, Performance of WMA Technologies: Stage I—Moisture Susceptibility. See *NCHRP Report 763.*

NCHRP Project 09-52, Short-Term Laboratory Conditioning of Asphalt Mixtures. See *NCHRP Report 815.*

The unique design and construction techniques that make WMA possible—indeed, the lower temperatures that make WMA desirable—raised questions about performance among practitioners. As the states' research program, NCHRP responded with major research efforts to address these questions.

Moisture Susceptibility. Introducing water to create a foamed binder is common in WMA preparation. Practitioners, however, were concerned that this practice could increase moisture susceptibility in WMA pavements. The lower WMA construction temperatures might also slow or prevent water dissipation, further contributing to the potential problem.

The foaming process introduces water in the hot asphalt binder.

Images from NCHRP Report 807

Researchers with Texas Transportation Institute (TTI) tackled this issue in NCHRP Project 09-49. Results from laboratory and field tests demonstrated that WMA is not necessarily more susceptible to moisture than HMA. However, the research suggested that construction of WMA pavements in warm weather, before the onset of winter, is desirable.

Another notable part of this research project was the development of laboratory test protocols to condition WMA specimens that mimic product behavior and aging in the field. This protocol will provide ongoing utility as a WMA investigation and assessment tool.

Conditioning. The high construction temperatures for traditional HMA contribute to necessary pavement stiffening in the short term after construction. The lower temperatures associated with WMA raised concerns about reduced rutting resistance after placement.

NCHRP Project 09-52, also conducted by TTI, showed that the stiffness of WMA in the field tends to be lower than HMA at the time of construction but becomes equivalent with HMA over time. Researchers also analyzed various factors that impact aging, such as the presence of recycled materials and the properties of aggregate, and provided guidance for pavement designers to consider given these different factors.

This research also considered whether traditional laboratory tests for HMA-aging properties could be used for WMA and further verified the laboratory aging protocols developed in NCHRP 09-49.

Ultimately, these projects together showed that both moisture susceptibility and conditioning are important factors to consider when using WMA, but they can be accounted for with proper design and construction.

The use of reclaimed asphalt pavement in WMA can impact the aging process.

Image courtesy of New York City Department of Design and Construction

SECTION 2

Side-by-Side Evaluation with Hot Mix Asphalt

NCHRP Project 09-47A, Properties and Performance of Warm Mix Asphalt Technologies. See *NCHRP Report 779*.

NCHRP Project 09-49A, Performance of WMA Technologies: Stage II—Long-Term Field Performance. *NCHRP Research Report 843*, forthcoming.

To better understand WMA performance and assess it as an alternative to traditional HMA pavement, NCHRP conducted side-by-side comparison research studies.

In NCHRP Project 09-47A, researchers at the National Center for Asphalt Technology (NCAT) compared the properties and field performance of WMA and HMA. The principal finding of the research was that over the first several years of service, the differences in material properties between WMA and HMA did not affect pavement performance.

Researchers also compared production and laydown procedures as well as emissions. The resulting data verified existing assumptions about WMA: The reduced temperatures used in WMA production and laydown yielded lower energy consumption and emissions and reduced worker exposure to breathable fumes.

A logical extension of NCHRP 09-47A was to compare WMA and HMA performance over the longer term. In NCHRP Project 09-49A, recently completed by a Washington State University-led team, researchers evaluated typical forms of distress—transverse and longitudinal pavement cracking, as well as wheel path rutting—for as long as 10 years after construction.

They found that WMA and HMA pavements had comparable long-term field performance. Moreover, moisture-related distress was not found in the field for either the WMA or HMA pavements, demonstrating further that these are viable alternatives for long-life asphalt pavements.

HMA (above) and WMA (below) at the asphalt plant.

Images courtesy of FHWA

SECTION 3

Developing National Mix Design Protocols

NCHRP Project 09-43, Mix Design Practices for Warm Mix Asphalt. See *NCHRP Reports 691* and *714*.

NCHRP Project 09-52, Short-Term Laboratory Conditioning of Asphalt Mixtures. See *NCHRP Report 815*.

NCHRP Project 09-53, Properties of Foamed Asphalt for Warm Mix Asphalt Applications. See *NCHRP Report 807*.

To facilitate the use of WMA on a large scale, NCHRP research sought to establish mix design protocols.

Comprehensive WMA Guidance. Through NCHRP Project 09-43, researchers at Advanced Asphalt Technologies, LLC, developed WMA mix design methodologies to complement methods used for HMA. Researchers found that given the similarities in design and construction between these two types of asphalt, a separate, stand-alone design method for WMA was not warranted.

Instead, they recommended expanding AASHTO specification *R-35: Standard Practice for Superpave Volumetric Design for Asphalt Mixtures* to include specific consideration of WMA. The WMA specification language developed in NCHRP 09-43 was approved and published as Appendix X2, which presents special WMA volumetric design practices to be used in conjunction with standard HMA practice.

NCHRP also published *NCHRP Report 714: Special Mixture Design Considerations and Methods for Warm-Mix Asphalt*, an expansive WMA design methodology intended for engineers and technicians as a supplement to *NCHRP Report 673: A Manual for Design of Hot-Mix Asphalt*. The findings explain how WMA differs in the five major steps of design and analysis: selection of materials, design of aggregate structure, selection of binder content, evaluation of moisture sensitivity, and analysis of performance.

Unique WMA Guidance. Other NCHRP design guidance addresses areas of WMA design that are different from HMA, such as the use of foaming. In NCHRP Project 09-53, TTI researchers determined which properties of foamed asphalt binders most influenced asphalt mixture performance. They used this information to develop laboratory protocols and mixing procedures for foamed WMA.

A notable outcome of this research was the identification of moisture targets for use in foamed asphalt. The research showed that exceeding approximately 2 percent moisture reduces WMA workability and that using moisture content in the range of 1.5 to 2 percent yielded WMA with equivalent performance to control HMA. In practice, moisture levels in foamed asphalt had tended to be higher than this, making the NCHRP 09-53 results invaluable for agencies and contractors aiming to deliver high-performance WMA pavements.

Benefits of WMA include improved workability and reduced energy requirements.

SECTION 4

Important Work Continues

NCHRP Project 09-49B, Performance of WMA Technologies: Stage I—Moisture Susceptibility Validation. See *NCHRP Report 817*.

NCHRP Project 09-52A, Short-Term Laboratory Conditioning of Asphalt Mixtures. In progress.

NCHRP Project 09-55, Recycled Asphalt Shingles in Asphalt Mixtures with Warm Mix Asphalt Technologies. In progress.

While completed NCHRP research has framed, examined, and answered critical questions related to WMA, additional research efforts are ongoing.

In some cases, follow-up research is used to build upon and validate existing findings. This is the case with NCHRP Project 09-49B (completed) and NCHRP Project 09-52A (in progress). As reported in *NCHRP Report 817*, NCHRP 09-49B validated the thresholds established for the moisture susceptibility testing in NCHRP 09-49 using data collected from 89 field projects across the United States. NCHRP 09-52A is validating short-term aging conditioning thresholds proposed in NCHRP 09-52 through further evaluation of the field pavements studied in that project. These results help fine-tune protocols to better meet the needs of mix design engineers.

Other current NCHRP research studies aim to answer new and ongoing questions. For example, in NCHRP Project 09-55, researchers are examining whether WMA becomes hot enough to fully activate the age-hardened asphalt found in postconsumer waste shingles (or tear-off shingles). NCAT researchers are conducting laboratory and field studies, to be completed in 2017, to compare the performance of WMA and HMA constructed with tear-off shingles. The research also includes tests on asphalt constructed with manufacturers' waste shingles.

The most common use for recycled asphalt shingles is in roadway pavements.

Image courtesy of King County, Wash.

Image courtesy of FHWA

SECTION 5

Supporting Broad Use of WMA

NCHRP Project 20-44(01), Increasing WMA Implementation by Leveraging the State-of-the-Knowledge

NCHRP supports continued implementation of WMA through targeted funding that accelerates WMA use and through ongoing efforts to facilitate AASHTO adoption of NCHRP findings.

Targeted Support: 2017 Workshop. Even though WMA has enjoyed rapid growth in the United States, its deployment varies by state, and barriers to wider use still exist.

TRB's committee on Critical Issues and Emerging Technologies in Asphalt (AFK10) spearheaded an effort to develop a workshop titled "Increasing WMA Implementation by Leveraging the State of the Knowledge." Scheduled for spring 2017 and funded through NCHRP Project 20-44, the workshop will bring together representatives from state DOTs that are leaders in WMA use as well as agencies that are new to the technology.

The event will provide opportunities for highway agencies to showcase efforts to overcome the barriers and risks (both real and perceived) of more widespread use of WMA. Participants will receive detailed resources related to specifications and practices that they can consult to further the use of WMA.

Implementation a Part of Every NCHRP Project. Beyond special projects like the 2017 workshop, NCHRP support for WMA implementation is an everyday activity.

A common thread among all NCHRP projects described here is the concerted effort among NCHRP staff, project panels, AASHTO committee members, and research investigators to ensure that the NCHRP research results can be readily adopted.

For many WMA research efforts, that means putting the results in a format that can be used in AASHTO balloting for national specifications. This extra legwork up front saves a great deal of time for AASHTO committee members, most of whom are volunteers from state DOTs.

Moreover, NCHRP encourages discussions of specification language and draft findings among practitioners before research projects are completed. This helps raise and resolve questions before the research results are final.

Together, these efforts help speed approval and expedite the delivery of critical guidance into the hands of practitioners around the nation.

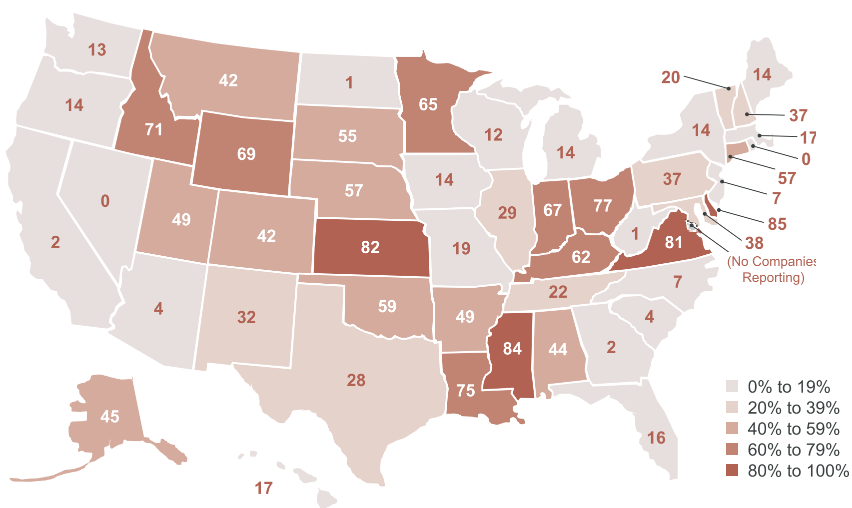

Image adapted from National Asphalt Pavement Association

WMA deployment varies dramatically by state. An FHWA-funded survey conducted by the National Asphalt Pavement Association shows estimated total tons of WMA produced in each state in 2014.

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