Executive Summary, Research Readiness Level Assessment, and Technology Transfer

Nebraska Balanced Mix Design – Phase I and Phase II

Research Benefits

The results of this study will provide significant insights to the current and future mixture designs and criteria by addressing major pavement distresses like rutting, cracking, and moisture damage. A special focus will be given to high recycled mixtures modified by additives like recycling agents and antioxidants. This study will improve the current mixture design method (i.e., Superpave) in Nebraska, where currently only volumetric characteristics are considered and the effects of additives such as recycling agents, antioxidants, polymers, and fibers cannot fully be addressed. More than that, the BMD method can be employed to design asphalt mixtures containing high RAP materials based on the fundamental properties of mixtures that can better address the main modes of distress: rutting, cracking, and moisture damage.

Phase I Objectives

The aim of this research is to establish benchmarks for current and future mixture designs and address rutting, cracking, and moisture damage resistance in more detail, especially with a focus on high recycled mixtures and major binder modifications using recycling agents and antioxidants. To this end, the BMD performance tests in high temperatures In addition, moisture performance tests will be included in the Nebraska BMD. Long-term aging protocols will be applied to the mixtures to address cracking resistance more accurately. The field evaluation will be conducted on pavement sections and field data will be collected to establish pass/fail thresholds for future quality assurance.

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Background

Typically, asphalt mixtures are designed under the Superpave system, in which the proportioning of the aggregates and asphalt binder is based on the aggregate quality characteristics and mixture volumetric properties such as air voids, voids in the mineral aggregate, and voids filled with asphalt. Mixtures designed with high amount of asphalt can be susceptible to rutting, while those with low asphalt content are prone to cracking, raveling, or other durability related pavement distresses. One of the largest shortcomings of current design procedures is the lack of long-term materials aging protocol. Therefore, performance tests should be included as part of the mixture design procedure to ensure the desirable field pavement performance. Many performance tests have been proposed for the evaluation of the rutting resistance (e.g., Hamburg Wheel Track Tester, Gyratory Stability, IDEAL Rutting Test, and High-Temp Indirect Tensile Test), cracking resistance (e.g., Semi-circular Bending Test and IDELA Cracking Test, and moisture susceptibility (e.g., Indirect Tensile Strength, Hamburg Wheel Track Tester) of the asphalt mixtures. In Balanced Mix Design (BMD), two or more mechanical tests are coupled to quantify the mixture resistance against different forms of distress. To be able to fully implement the outcomes of this research, the field evaluation must be conducted, and field data must be collected to establish pass/fail thresholds for future quality assurance (QA) and acceptance (QC) purposes.

Phase I Conclusion

Balanced mix design (BMD) is an alternative concept for designing asphalt mixtures that mainly focuses on performance of mixtures rather than only volumetric analysis. Using this concept, it would be possible to account for the incorporation of recycled asphalt mixtures, warm technology, polymers, rejuvenators, and other foreign additives, as well as external effective factors on the mix design such as environmental effects. This project sought to investigate performance-based methodologies for the asphalt mix design by taking a step to develop a preliminary Nebraska BMD framework. With that, selection of appropriate performance tests, finding a functional laboratory aging protocol, and defining performance test criteria were the main long-term goals developed in this phase of study. Three main types of distresses were taken into consideration (rutting, fatigue cracking, and moisture susceptibility), and a set of performance tests including well-established tests, were selected to capture these distresses on two types of high-performance commonly used asphalt mixtures in Nebraska (SLX and SPR). In terms of rutting and fatigue cracking, IDEAL-RT and IDEAL-CT tests showed the highest correlation to well-established tests as well as significant sensitivity and accuracy in terms of results. For the moisture damage resistance tests, no strong correlation was found between well-established and surrogate tests, except for the G-stability test that showed some potential to be considered for future studies. In terms of long-term aging methods, the NCAT protocol was found to be more severe than NCHRP 09-54, however, selecting an appropriate long-term aging protocol for the Nebraska BMD will be done after long-term data analysis in the next phases of this study. Finally, an initial understanding of each test's pass/fail criteria was achieved based on the test result values obtained from historically acceptable asphalt mix design in the state.

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Phase I NDOT Recommendations Based Off Research Project – 2023 – RRL2

This research project will help define the Nebraska BMD method which considers 3 main distresses: rutting, fatigue cracking, moisture damage. For implementation consideration, the field evaluation must be conducted, and field data must be collected to establish pass/fail thresholds for quality assurance (QA) and acceptance (QC) purposes. The findings of this research will help establish pass/fail thresholds for the BMD mix design method which is currently in progress. This can improve Nebraska's pavement engineering: materials, design, and maintenance. The successful development of BMD along with pass/fail thresholds may provide cost savings or could increase costs but can potentially provide higher performing asphalt pavements.

This research is Phase I with the follow-up project FY23(016) Nebraska Balanced Mix Design – Phase II, starting July 2022.

- *As provided by Robert Rea, Lead TAC Member*

Phase II Objectives

The aim of this research is to establish pass/fail thresholds for future QA/QC for the BMD mix design. To this end, several projects across the state will be selected, the condition of pavements before paving will be evaluated, and after paving will be monitored. In addition, mixes from each selected project will be collected and the BMD performance tests selected from the phase I of the BMD project will be carried out. The results of laboratory tests will be compared with field performance data to establish pass/fail thresholds.

Interested in finding out more?

Phase I Final Report Available: HERE

Phase II Final Report Available: HERE

Phase II Conclusion

This study aimed to propose a performance-based framework to evaluate highly recycled asphalt mixtures containing polymer-modified binders for potential use in a balanced mix design (BMD) specification in the state of Nebraska. For that, loose and compacted mixtures were directly collected from plant and field projects within a benchmarking study, subjected to an extensive experimental program. The laboratory investigation employed different monotonic tests recommended in BMD Phase 1, as well as the dynamic modulus test. Three long-term aging protocols were investigated in terms of their impact on the mechanical, rheological, and chemical characteristics of asphalt mixtures and binders. Moreover, field assessments with cores and pavement management system data were added to the analysis. Results evaluated the sensitivity and significance of various tests for characterizing rutting and cracking resistance across mixtures varying in binder sources, grades, recycled contents, and warm mix additives. The variability and discrimination potential of performance-based parameters were identified, and suitable performance tests were suggested for the BMD framework considering the type of mixtures and site conditions of this study. The preliminary threshold criteria for each performance test were selected using a mechanistic-empirical approach considering three representative structural layers. Regarding the aging protocol, while the studied aging protocols yielded similar cracking resistance trends, their aging severity differed. Considering mechanical, chemical, and rheological similarities, an adjusted long-term aging protocol was selected for the potential implementation in the state's BMD framework. Reheating and dwelling time impacted performance indices, showing they could be considered in criteria selection. The selected performance-based parameters and threshold criteria corroborated with the results from field rutting, roughness, and cracking assessments, which further verify the outcomes. It was recommended to validate the selected performance tests, associated preliminary criteria, and aging protocol using more extended field data collection.

Executive Summary, Research Readiness Level Assessment, and Technology Transfer

Phase II NDOT Recommendations Based Off of Research Project – 2025 – RRL2

This research provides the Nebraska Department of Transportation (NDOT) with a foundational framework for Balanced Mix Design (BMD). While the department is considering BMD, additional data is essential for a full-scale assessment. Specifically, NDOT must identify where BMD mixtures fail Rutting Tolerance (RT) and Cracking Tolerance (CT) tests. These testing methodologies present two major limitations: they rely on monotonic, room-temperature testing and exhibit test variability due to sample preparation and aging methods. Additionally, inconsistencies introduced by lag and dwell times in current testing protocols contribute to variability. To address this, a standardized testing protocol is needed to mitigate these effects and ensure consistent results and is currently being studied both internally and on a national level. For program laboratory acceptance testing, reheating samples is often necessary, but threshold values distinguishing between original and reheated samples must be established to ensure accuracy. Because the shift to BMD represents a significant change, NDOT is committed to a cautious, data-driven approach to evaluate for potential use to support mix designs and future mixture and binder specification parameters.

- *As provided by Robert Rea, Lead TAC Member*

Research Readiness Level (RRL) Assessment

RRL 2

Level 2: Applied Research/Proof of Concept/Lab-Level

Research validated and demonstrated in a laboratory setting.
Remained Level 2: Applied Research/Proof of Concept/Lab-Level (Phase I)

Technology Transfers:

Phase I:

Principal Investigator did not have any technology transfer for this research project.

Phase II:

Webinars/Presentations

- Yazdipanah, F., Khedmati, M., Rea, R., Teixeira, J., & Haghshenas, H. F. (2025). Development of a balance mix performance framework for assessing high-recycled asphalt mixtures' resistance: a study integrating laboratory and field findings. Road Materials and Pavement Design, 1-20.

Journal Papers Submitted for Review and In Progress Journal Papers and Theses

- Yazdipanah, F., Teixeira, J., Haghshenas, H.F. (2025). Balanced Mix Design for Highly Recycled Asphalt Mixtures: Laboratory and Field-Testing in Nebraska. Presented at ASCE's International Conference on Transportation & Development (T&DI), Glendale, Arizona, June 8-11, 2025.
- Teixeira, J.E. S. L. (2024). University of Nebraska Research Updates: UNL Asphalt Research Program. Presented at 2024 Nebraska Asphalt Paving Conference, Kearney, NE, February 27-28, 2024.
- Teixeira, J.E. S. L. (2025). University of Nebraska Research Updates: UNL Asphalt Research Program. Presented at 2025 Nebraska Asphalt Paving Conference, Kearney, NE, February 4-5, 2025.

This brief summarizes Project SPR-FY22(002) and SPR-FY23(016):
"Nebraska Balanced Mix Design – Phase I"
"Nebraska Balanced Mix Design – Phase II"
Nebraska Department of Transportation Research Program