Office of Research and Implementation

FFY2025 Request for Proposals

Reference SPR Item # 2500

Research Problem Statement Title:

Asphalt Binder Test (ABT) for Quick Performance Grade of Asphalt Binder

Problem Statement:

In recent years, several newly constructed asphalt pavements in Oklahoma have exhibited premature (some within a year) distresses and failures. One of reasons for this type of failure could be the use of inferior (sub-standard) binder during construction. Oklahoma DOT has quality assurance protocols in place to make sure that the binder satisfies the required rheological and performance properties and is of correct performance grade (PG). Although satisfactory, the current testing protocols are time-consuming and labor-intensive, and at times could not detect the out-of-specification binders before/during construction. Also, with ODOT's effort to broadly implement Balanced Mix Design (BMD) in Oklahoma, ensuring the correct PG grade of the binder is becoming increasingly more important to ensure performance. The Asphalt Binder Tester (ABT) is a novel rapid testing device that can determine the continuous PG of asphalt binder accurately (95% accuracy) in a significantly reduced time. The ABT was developed jointly by the FHWA and Laser Tech, Inc. (LTI) under a Cooperative Research and Development Agreement (CRADA). This easy-to-use testing device requires only 3-ounces of asphalt binder, conditioned at 25°C (77°F), to run the test. The device uses an air jet to produce a 20-second load on the asphalt binder sample and then allows a 70-second recovery time. The resulting deflection and recovery of the sample over this 90-second period is measured using a laser deflectometer, which is integrated with the ABT. The ABT protocol uses an Artificial Neural Network (ANN) model in which the deflection and recovery curves measured in the test are used as the input and the continuous PG of the asphalt binder sample as the output. The ANN model has been trained using test data of more than 1,000 asphalt binders nationally. The device is relatively small and more portable than most rheological testing equipment. Also, calibration is efficient and less complicated. The ABT has the potential to

increase the detection of out-of-specification binders before they are used in asphalt pavement construction, thereby increasing performance and reducing maintenance costs significantly.

Proposed Research:

The proposed study will evaluate the continuous PG of commonly used neat and polymer-modified binders in Oklahoma from different sources and verify the results with the traditional AASHTO M 320 method to ensure confidence. In addition, asphalt binder modified with Engineered Crumb Rubber (ECR) and US Polyco Rapid Digestion Process (RDP) rubber will be evaluated. In the next step, the continuous PG grades of binders blended with RAP extracted binders will be tested using the ABT and the test data will be used to train the ANN model. Binders extracted from asphalt pavements exhibiting premature distresses and failures will be tested and included in the ABT database. Effect of binder extraction and recovery on the continuous PG may be studied selectively and the results used to introduce a correction factor in the ANN model. The results from this study will allow ODOT to deploy an innovative testing method for cost-effective and time-efficient determination of continuous PG grades of asphalt binders and identify out-of-spec binders before they are used in construction. Also, this study will enhance broad implementation of BMD, including mixes with high RAPs. Continuous PG is one of the most important properties in BMD for mixes with and without recycled materials.

Suggested Tasks (to include but not limited to):

Task 1 Conduct a literature review of existing information on the asphalt binder test.
Task 2 Evaluate using ABT the continuous PG of commonly used binders in Oklahoma.
Task 3 Verify ABT test results with AASHTO M320 method.
Task 4 Test binders from recycled asphalt pavement (RAP), binders from distressed and failed pavements, engineered crumb rubber, and rapid digestion process rubber.
Task 5 Provide hands on training for ODOT bituminous technicians.
Task 6 Final report and implementation guideline.

Implementation:

This Implementation will take place at the bituminous laboratory of ODOT Materials Division.

Benefits:

The potential benefits of the ABT are expected from a combination of reduced testing costs, increased testing capacity, decreased latency time for test results, and a potential increase in the average quality of asphalt pavement. A detailed analysis of asphalt binders in a shorter period would allow ODOT to monitor asphalt binder quality in a more timely and economical manner. Also, implementation of BMD will benefit from this study, as this design methodology gains momentum and mixes with increased amounts of RAP, rubber and other recycled materials are used in paving. Safety for technicians will increase due to less time spent on the more extensive

test methods of AASHTO M 320. Additional value would be added for decision makers due to increased knowledge of the full continuous PG rather than the current interim test that just provides a broad scope of binder quality.

Deliverables:

All projects require the submission of the following reports:

- Monthly Progress Reports
- Multi-Year Projects require a Year-end Annual Report
- Copies of the project Draft Final Report in Microsoft Word and ADA accessible Adobe Acrobat pdf electronic formats
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The Year-end Annual Report, Draft Final Report, Final Report and Color Article should be submitted to satisfy all federal and state requirements pertaining to the accessibility of documents including but not limited to:

- Oklahoma State Statute 62 § 41.5e and the Americans with Disability Act (ADA) of 1990, 42 USC 12.01 et seq.

The PI must also participate in the following project meetings:

- New project initiation meeting
- Semi-annual project meeting
- Close-out project meeting
- Continuing project meeting

Estimated completion time twenty-four months.

Existing Research found in light literature search:

Federal Highway Administration (2023)
"Exploration of Curing Characteristics of Epoxy-Modified Asphalt"
https://journals.sagepub.com/doi/abs/10.1177/03611981221150445
A study was conducted on epoxy-modified asphalt (EMA) diluted with two binders of a different chemical structure, to understand the effect of curing rates and long-term postcuring characteristics. Dynamic shear rheometer test results did not show a clear trend of curing time and dosage percentage impact for the two base binders; parallel-plate geometry may not be well-suited to study EMA because of the thermosetting properties of curing. The asphalt binder test (ABT) method was used to assess the effect on rheology of short-term and long-term curing. Analysis of the ABT data to date suggests that the binder source has a notable effect on the composite properties. The impact of long-term storage was also found to be dependent on the asphalt binder used. Findings from this study were also applied to two field binders; one was modified using styrene-butadiene-styrene polymer, and the other contained epoxy. Curing times

were determined using the ABT test. The Dongre Workability Test (DWT) was also conducted on open-graded friction course mixes and the mix curing times were found to be significantly higher than those determined on the binders. A method based on DWT data to determine a "workability window" was also explored. The Strategic Highway Research Program (SHRP) sol-type binder AAG-2 was found to exhibit little to no reactivity with the epoxy modifier used in this study. The SHRP gel-type binder AAD-2, however, was found to be highly reactive. The short-term curing temperature was found to affect the rate of curing for base binder AAD-2. The curing rate was found to be highest at 165°C followed by 120°C, and the rate was at its slowest at 25°C. AAG-2 did not show any onset of curing at either temperature.

Transportation Research Record 2023
"Understanding the Sensitivity of Mixture Cracking Performance Tests to Binder Properties and Long-Term Aging"
https://journals.sagepub.com/doi/abs/10.1177/03611981231170629
The asphalt community is focused on the paradigm shift in mixture design from volumetrics to an optimization procedure based on performance tests called balanced mixture design (BMD). Laboratory performance tests are being assessed for their relationship to binder properties and field performance. However, existing BMD practice does not account for long-term oven aging (LTOA). This gap limits the appropriateness of thresholds and the potential of BMD for improving pavement performance. The Federal Highway Administration's Asphalt Materials Research Program has launched a three-phase study to provide insights into relevant performance testing. Phase I compared seven cracking performance tests after short-term aging, whereas Phase II evaluated the sensitivity of selected performance tests to LTOA. Phase III, in which seven loose mixtures collected from Montana, Vermont, Ohio, and Florida were subjected to LTOA, is presented in this paper. The indirect tensile cracking, Illinois Flexibility Index, dynamic modulus, and cyclic fatigue tests were employed before and after two proposed 2 LTOA conditioning protocols. Additionally, chemical, rheological, and fracture properties were obtained from extracted binders to obtain a better understanding of the impact of binder properties on mixture performance indices. Results illustrate that LTOA is critical for a comprehensive BMD framework and, thus, some of the testing protocols, indices, and thresholds need to be refined further.

Journal of Testing and Evaluation China (2023)
"Evaluating the Creep Deformation and Elastic Recovery of Different Polymer-Modified Bitumens Using a New Bitumen Quality Control Test"
https://asmedigitalcollection.asme.org/testingevaluation/article-abstract/51/4/2632/1192382/Evaluating-the-Creep-Deformation-and-Elastic?redirectedFrom=fulltext
To quickly and accurately evaluate the creep deformation and elastic recovery performance of polymer-modified bitumen, a new bitumen quality control test (QCT) was carried out to analyze the creep deformation and recovery properties of styrene-butadiene-styrene (SBS)-modified bitumen and rubber powder–modified bitumen with different modifier dosage at 15°C, 20°C, 25°C, and 30°C. At the same time, the creep deformation speed of different polymer-modified bitumens was also investigated based on the QCT results. Then, the penetration and dynamic shear rheological tests were implemented on these binders to establish the relationship between QCT indexes (maximum creep deformation and deformation recovery rate) and physical–rheological indexes (penetration and complex viscosity). Results show that the creep deformation

resistance and elastic recovery ability of bitumen enhance gradually with the increase of both SBS and rubber powder. Between SBS and rubber powder, SBS exhibits a more significant influence on the creep deformation resistance and elastic recovery properties of bitumen than rubber powder under the same temperature and modifier dosage. A polymer-modified bitumen with smaller penetration and bigger complex viscosity is prone to better creep deformation resistance and elastic recovery performance.

Construction and Building Materials (2023)
"Adhesive behavior and pavement performance of asphalt mixtures incorporating red mud as a filler substitute"
https://www.sciencedirect.com/science/article/pii/S0950061821016159?casa_token=HVbVgzDwMWEAAAAA:F5hWljHROH84JLQe9WSRS5kQy3HorvDUp8YbgOj0JBHkxk4BfW6KdOn1nEHxfGQY2atprMZMWp8
With the massive exploitation and utilization of no-renewable natural resources, good-quality road building materials has been becoming scare and it is an urgent demand to explore and develop alternatives. This study investigated feasible approaches of using red mud as a filler substitute to replace limestone powder in asphalt mixtures. In order to elaborate its influence on adhesive behavior, surface energy components of various fillers, base bitumen, the powder-bitumen interface and the aggregate-asphalt mastic interfaces were calculated and characterized. The mechanical properties of asphalt mastics and asphalt mixtures were assessed by using Quality Control Test (QCT), Hamburg Wheel Tracking (HWT) test and Simple Performance Test (SPT). Referring to the thermodynamic theory, the adhesive performance of the red mud-bitumen interface can be improved by the addition of hydrated lime or Portland cement and the moisture resistance of the aggregate-asphalt mastic bond can be enhanced. It was found that incorporating the red mud can improve the stiffness and the elastic recovery of asphalt mastic, which in turn had a potential to improve the high-temperature performance of the corresponding asphalt mixtures. Regarding to pavement performance, replacing limestone powder by red mud improved the rutting resistance of asphalt mixtures and 3 the moisture resistance can be enhanced by incorporating a certain amount of hydrated lime or Portland cement.

Green and Intelligent Technologies for Sustainable and Smart Asphalt Pavements (2023)
"Study on the influence of red mud on the durability of asphalt mixture and its modification"
https://books.google.com/books?hl=en&lr=&id=mEpREAAAQBAJ&oi=fnd&pg=PA115&ots=pOxfJK2KcT&sig=ioMPta6gv_ZeCRtze5UYZuWK67Q#v=onepage&q&f=false
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rutting resistance of asphalt mixtures and the moisture resistance can be enhanced by incorporating a certain amount of hydrated lime or Portland cement.

Transportation Research Record (2023)
"Case Study on Using Warm Mix Asphalt at Reduced Production Temperatures for Balanced Mix Design"
https://journals.sagepub.com/doi/abs/10.1177/03611981231214230
This study provides a case study to illustrate the feasibility of using warm mix asphalt (WMA) at lower production temperatures to design asphalt mixtures with balanced rutting and cracking resistance in a laboratory setting. Two balanced mix design (BMD) modification approaches were evaluated to modify an existing Superpave mix design with unbalanced performance because of inadequate cracking resistance: (1) adding asphalt binder and (2) using WMA with a surfactant-based chemical additive. The modified mix designs were tested with the indirect tensile asphalt cracking test and high-temperature indirect tensile strength test to determine compliance with the Alabama Department of Transportation's (ALDOT's) BMD performance requirements. The original and modified mix designs were then tested in the modified overlay test to characterize their reflective cracking resistance, and the results were input into the Texas Asphalt Concrete Overlay Design System (TxACOL) software for theoretical asphalt overlay design simulations. Finally, asphalt binder testing was conducted to determine the impact of BMD modifications on the rheological properties of extracted binders. Laboratory testing showed that both BMD modifications improved the cracking resistance of the mix design but through different mechanisms. All the modified mix designs met ALDOT's BMD requirements with balanced rutting and cracking resistance at their corresponding optimum binder content (OBC), which was 0.4%–0.7% higher than the volumetric OBC, respectively. TxACOL simulations showed that BMD modifications significantly improved the predicted reflective cracking performance and service life of asphalt overlays, but the improvement varied depending on the underlying pavement and traffic conditions.

Construction and Building Materials (2023)

"Performance of warm asphalt mixtures containing reclaimed asphalt pavement, an anti-stripping agent, and recycling agents: A study using a balanced mix design approach"
https://www.sciencedirect.com/science/article/pii/S0950061822032895?casa_token=kt5sGIMSIIMAAAAA:mW_XyURqolXt_5jX1xznh1JtDH3--TQ6mfI4Y9yRjJGgW5XOXegkhg5y9qiGaagUrO9Gh6dAZS4

This research aims to use a balanced mix design (BMD) approach to investigate the effect of recycling agents (RAs) and an anti-stripping agent on the mechanical properties of warm-mix asphalt (WMA) containing different levels of reclaimed asphalt pavement (RAP). The BMD used three RAs (aromatic extract, triglycerides and fatty acids, and tall oil), an amidoamine WMA additive (PAWMA®), and an anti-stripping agent (Zycotherm®). The Dynamic Creep (DC), Indirect Tensile Strength (ITS), and Semi-Circular Bending (SCB) fracture tests were respectively used to evaluate the rutting, moisture susceptibility, and cracking resistance of mixtures. In addition, two-dimensional and three-dimensional (2-D and 3-D) performance interaction diagrams were developed as typical approaches for the BMD of asphalt mixtures. For mixtures with RAP, the results indicated that the aromatic extract and tall oil RAs decreased the moisture susceptibility, while triglycerides and fatty acids increased the moisture susceptibility. In addition, the RAs generally decreased the rutting resistance of mixtures while they increased the cracking resistance. This effect was more noticeable in the mixtures treated with triglycerides and fatty acids. The results also showed that introducing PAWMA® and Zycotherm® to the mixtures improved their resistance to moisture damage, cracking, and rutting.

COOPERATIVE RESEARCH PROGRAMS (2022)

"Evaluation of the Asphalt Binder Quality Tester"
https://nap.nationalacademies.org/catalog/26603/evaluation-of-the-asphalt-binder-quality-tester

This report documents the evaluation of the Asphalt Binder Quality Tester (ABQT), a device that was researched and developed by FHWA's Research and Technology (R&T) Program. The ABQT was developed under a cooperative research and development agreement between FHWA and Laser Technology, Inc.

The ABQT is a rapid testing device that measures deflection and recovery in a sample of asphalt binder and then estimates the performance grade of the binder sample. Binder quality is an important component of asphalt quality, affecting the quality and performance of asphalt pavement. Compared with most existing binder testing equipment, the ABQT is smaller, requires less calibration, and uses smaller sample volumes, making it more portable and easier to use. The ABQT has the potential to provide test results more rapidly at a project site or in a state testing laboratory. This could allow an increased number of samples to be tested, which could help state departments of transportation (DOTs) and project managers to better detect out-of-specification binder before it is paved.

The ABQT was assessed under the TRB-FHWA Program Evaluation (TFPE) effort, which is part of a second stage of FHWA's R&T Evaluation Program. For Project TFPE-01, "Asphalt Binder Quality Tester," RTI International was tasked with evaluating the process by which ABQT research was selected and conducted. The effort included an evaluation of activities to promote the adoption of ABQT by state DOTs along with an assessment of barriers to adoption of the ABQT by public- and private-sector entities. A quantitative estimate of the potential benefits of the ABQT is also provided.

International Conference on Transportation and Development (2022)
"Implications of Changing Asphalt Binder Sources on Engineering Properties of Traditional and Balanced Asphalt Mixtures"
https://ascelibrary.org/doi/abs/10.1061/9780784484357.024
This paper reports on the impacts that different sources of asphalt binders, which satisfactorily met the grading requirements of a PG 70-22 binder, have on the mechanical performance of two Superpave mixtures, namely a traditional mix design and a balanced mix design. Five asphalt binders were acquired from different asphalt suppliers. Superpave mixtures were designed and produced with two different aggregate gradations, and similar recycled material content following both volumetric-based and performance-based design approaches. For performance testing, the Hamburg wheel tracking device and Texas overlay tester tests were used as the main rutting and cracking tests, respectively, during the design process. The Illinois Flexibility Index Test and indirect tensile asphalt cracking tests were performed as surrogate cracking tests. From this study, the voids in the mineral aggregate parameter does not differentiate the impact of changing the asphalt binder source. The mechanical tests were sensitive to changes in binder source, which demonstrated the importance of incorporating a performance testing stage to current design specifications. The asphalt mixtures denoted as balanced mix designs in this study yielded acceptable mechanical and volumetric properties regardless of the binder source.

Transportation Research Record, 2022)
"Examples of Successful Practices with State Implementation of Balanced Design of Asphalt Mixtures"
https://journals.sagepub.com/doi/abs/10.1177/03611981221084696
State departments of transportation (DOTs) are at various stages of implementation of their balanced mix design (BMD) program. Some states have not yet started and may still be exploring the feasibility of integrating BMD within their asphalt pavement program, while others have already moved forward with implementation activities and are currently at different stages of the implementation process. The latter have valuable experience and lessons learned that could facilitate the implementation of a BMD program into practice to improve long-term pavement durability and performance. Thus, an effort was initiated to identify and put forward positive practices from state DOTs when implementing BMD and performance testing of asphalt mixtures. To accomplish this objective, information was collected through virtual site visits, and other means made necessary by the coronavirus pandemic, with seven key state DOTs. As a result of this effort, it was identified that five state DOTs out of seven use Approach A for the BMD process as defined in AASHTO PP 105-20, and one state DOT uses a combination of Approach A and Approach B. One state DOT also allows for Approach C while another state DOT allows for Approach D. Eight major tasks for the overall process for implementing BMD as part of mixture design approval and acceptance are established, and positive practices with examples for each task are provided. Those successful efforts used by state DOTs could be considered by other state DOTs in their effort to implement BMD within their asphalt pavement program.

Transportation Research Record (2021)
"Laboratory and Field Evaluation of Pre-Treated Dry-Process Rubber-Modified Asphalt Binders and Dense-Graded Mixtures"
https://journals.sagepub.com/doi/abs/10.1177/03611981211011480 6

Pre-treatment of ground tire rubber is emerging as a popular method to incorporate rubber particles in dense-graded asphalt mixtures. This study investigates the effects of a chemically engineered Dry-Process Ground Tire Rubber (DP-GTR) modification in asphalt binders and mixtures. The DP-GTR is comprised of rubber particles measuring 400 to 600 µm in diameter (minus #30 mesh) coated with a non-elastomeric liquid. No change in aggregate gradation is necessary in DP-GTR modification of asphalt mixtures. In this study, the effects of DP-GTR modification on binder properties were measured by dynamic shear rheometer, Multiple Stress Creep and Recovery (MSCR), and bending beam rheometer tests. Additionally, mixture properties measured by three cracking tests: Disk-shaped Compact Tension (DC[T]) test, Illinois Flexibility Index, and indirect tensile asphalt cracking test and one rutting test (Hamburg wheel track test) were evaluated. Results showed: (a) 10–12°C bump on binder high temperature performance grade with 10% DP-GTR modification by weight of binder; (b) improvement in non-recoverable compliance in MSCR test indicated higher rut resistance; (c) increase in DC(T) fracture energy at low temperatures; (d) decrease in rut depth; and (e) decrease in flexibility index and cracking test index. Field performance of the chemically treated DP-GTR sections located in different states was examined to address discrepancies observed in the cracking tests. The cracking and rutting performance of all the field sections was good-to-excellent, suggesting that some of the currently popular simple cracking tests may not be able to properly assess the cracking resistance inherent in GTR-modified asphalt mixtures.

Minnesota Department of Transportation (2018)
"Balanced Design of Asphalt Mixtures"
https://rosap.ntl.bts.gov/view/dot/36534
A balanced mix design (BMD) sets a maximum asphalt content based on the rutting criterion and a minimum asphalt content based on cracking criterion. This project developed a BMD framework for the Minnesota Department of Transportation (MnDOT) and used it to evaluate materials from four Minnesota projects using the Illinois Flexibility Index, the IDEAL-CTAL-CT-CT Cracking Test Index by the Texas A&M Transportation Institute, and the Disk-shaped Compact Tension test for cracking and the Hamburg Wheel Tracking test for rutting. For the four test mixtures, the performance tests and the BMD procedure were successful in distinguishing the influence of asphalt content on cracking resistance and rutting resistance. There was fairly good agreement among the cracking tests for the asphalt content and only a slight deviation from volumetric asphalt content in most cases. The cracking and rutting performance criteria need to be refined for different applications based on characteristics such as climate, lift thickness, traffic level, and placement within the pavement structure.

FHWA Turner-Fairbank Highway Research Center (2017)
"Asphalt Binder Quality Test Presentation"
https://www.asphaltpavement.org/uploads/documents/Engineering_ETGs/Binder_201709/8_Youthcheff_TFHRC_Update.pdf

Federal Highway Administration (2014)
"Development of a Quality Control Test for Asphalt Binders"
https://trid.trb.org/view/1399562
An innovative, simple, and easy-to-use test method for quality assurance testing of asphalt binders at the mix plant was developed. This new method, the Binder Quality Control Test (QCT), uses an air jet to produce indentation and a laser deflectometer to measure the resulting deflection. The

QCT is conducted under constant stress and temperature similar to the traditional Penetration test (ASTM D5) except instead of the penetration needle, an air jet is used with a loading time of 20 s and a recovery time of 60 s under no load. Unlike the Penetration test, the QCT measures both the loading and recovery characteristics of a binder. The complete creep-recovery curve is measured stored. The measurement of recovery properties allows for successful discrimination of both unmodified and polymer modified binders. Several performance-graded and penetration-graded asphalt binders were tested with and without modifiers, which included polymers as well as Recycled Engine Oil Bottoms (REOB). At this time the QCT has the potential to be implemented as a control test, an informational test that would trigger more complex acceptance testing. Possible applications of the QCT method include an alternative to traditional Penetration testing, quick and easy determination of asphalt tank contamination issues, assistance in value engineering projects, and with formation of polymer modified binders. This paper describes the development and implications of using the QCT developed in this research.