NCAT Test Track Begins Seventh Research Cycle

The seventh cycle of accelerated performance testing launched this year at the NCAT Test Track and consists of new mixture performance sections, instrumented structural sections, and extended traffic sections.

Initially constructed in 2000, the NCAT Test Track is a 1.7-mile oval comprised of 46 main test sections sponsored on three-year cycles. The track is circled by a fleet of heavily loaded trucks resulting in 10 million equivalent single axle loads (ESALs) of traffic, while the performance of each test section is closely monitored over a period of two years. Forensic analyses of damaged sections are then performed to determine the contributing factors to pavement distresses. Investigations conducted during this stage include destructive testing such as trenching and coring, as well as additional laboratory testing as needed. Test sections are either reconstructed or remain in place for additional evaluation during the next cycle.

The 2018-2020 cycle includes continuing studies and new experiments in areas such as balanced mix design, rejuvenators, pavement preservation, and reflection cracking. Several new experiments for the seventh cycle are detailed below.

Cargill: Section N3
Cargill is sponsoring parallel testing at the Test Track and the Minnesota Department of Transportation’s MnROAD facility to determine how to best implement balanced...
Density is verified on Section N3 during the compaction process.

mix design procedures in asphalt mixes containing rejuvenators and high levels of reclaimed asphalt pavement (RAP). As part of the project, test sections made with Cargill’s Anova rejuvenator and a 45% RAP mix will be compared to control sections with lower RAP contents, measuring factors such as pavement ride quality, cracking, and rutting. By conducting experiments at both the Test Track and MnROAD, researchers will be able to monitor results in both northern and southern climate extremes.

Alabama DOT: Sections N10, N11
The objective of the Alabama Department of Transportation’s (ALDOT) study is to evaluate thinner overlay alternatives that are a durable option for pavement preservation. Thinlays are thin asphalt overlay mixes typically designed to be placed as thin as 5/8 of an inch.

Section N10 is a 4.75 mm nominal maximum aggregate size (NMAS) stone matrix asphalt (SMA) mix with a PG 76-22 binder. The Thinlay in N10 was placed at a thickness of 0.8 inches. Section N11 is a 4.75 mm dense-graded mix with a PG 67-22 binder. The Thinlay in N11 was placed at a thickness of 0.5 inches. A structurally sound pavement is needed in order to assess Thinlay performance. Therefore, a new intermediate asphalt layer was paved prior to the placement of each Thinlay.

Florida DOT: Sections E5, E6
The objective of the Florida Department of Transportation’s (FDOT) study is to evaluate the effect of changes in density on mixture durability. Recent national efforts have increased attention on raising in-place densities to improve durability.

Sections E5 and E6 have the same mixture, which is a fine-graded mix with 20% RAP and a PG 64-22 virgin binder. Both sections were divided into two subsections to result in four 100-foot subsections. The difference among the subsections is the density. E5A has a target 94% density, E5B has a target of 92%, E6A has a target of 90%, and E6B has a target of 88%. The laboratory portion of this study will include cracking and moisture susceptibility performance testing along with rheological and chemical tests of the extracted binders from each subsection. The field evaluation will be typical for the track and includes cracking, rutting, texture, and roughness (IRI).

Georgia DOT: Sections N12, N13
The Georgia Department of Transportation (GDOT) aims to find a cost-effective approach to reduce reflective cracking. The agency’s traditional approach has been to place a single surface treatment application with No. 7 stone over the existing surface before overlaying. The
open texture of the surface treatment is believed to spread out high strains at cracks or joints in the existing pavement so that underlying cracks are dissipated rather than reflected through to the surface. This approach, however, has not been as effective as desired.

In 2012, GDOT sponsored two test sections (N12 and N13) to evaluate two methods for reducing reflective cracking. One section used a double surface treatment with sand seal coat, and the other used an open-graded interlayer. After 20 million ESALs of trafficking, only 6% of the saw cuts in the double surface treatment section reflected through to the surface, while 51% of the saw cuts reflected through to the surface in the open-graded interlayer. GDOT is continuing to sponsor these two sections and adding six other treatments including a PETROMAT® fabric interlayer, a GlasGrid® interlayer, a chip seal with No. 7 stone, a chip seal with fractionated coarse RAP, an open-graded interlayer with an Ultrafuse® tack coat, and a rubber modified asphalt interlayer with Ultrafuse®. The sections have the same saw cut pattern and surface overlay mix as the 2012 GDOT test sections. Therefore, the factors affecting the reflective cracking performance are only the treatment methods.

Mississippi DOT: Section S2
The Mississippi DOT (MDOT) often faces challenging soil and aggregate base conditions when building or rehabilitating asphalt pavements. One approach has been to use lime and/or cement to stabilize the roadbed soil and base before placing the asphalt concrete layers. The new MDOT-sponsored structural section, S2, is meant to replicate common practice in Mississippi and provide valuable data for verification, calibration, and validation of mechanistic-empirical (M-E) design approaches.

Section S2 was excavated before the placement of 48 inches of a high plasticity Mississippi clay subgrade. The upper 6 inches of the MS subgrade was lime treated. The next 6 inches was a dirty-sand base layer treated with cement. Both layers were cured according to MDOT’s specifications before placing the asphalt concrete layers. The section is fully instrumented with pressure cells, strain gauges and temperature probes to provide critical data needed for M-E analysis.

Mississippi DOT: Section S3; Tennessee DOT: Section S4
The Mississippi and Tennessee Departments of Transportation are each sponsoring a rejuvenating fog seal experiment during this cycle. NCAT conducted a preliminary study to evaluate eight fog seals to determine which products would be used on the Test Track sections. The Federal Aviation Administration’s procedure P-632 (Bituminous Pavement Rejuvenation) was used to evaluate extracted binders two and four weeks after the application of the eight products on aged 1.5” mill/inlay asphalt pavement sections. Pavement surface friction characteristics after each fog seal application were also used in the screening process. The results were presented to MDOT and TDOT to assist them in the decision of which fog seal products to use on their respective Thinlay test sections.
Illinois Flexibility Index to evaluate cracking resistance.

Section N9 is a 2-inch mill-and-inlay using an ODOT 9.5mm NMAS mix containing 15% RAP and a PG 76-28 modified binder. Section S1 is a 5.5-inch mill-and-inlay using a 12.5 mm NMAS mix as the surface course over a 19 mm NMAS base course. Both mixes use a PG 70-28 modified binder. The surface mix has 12% RAP, while the base mix contains 30% RAP and a rejuvenator.

South Carolina DOT: Section S9
The South Carolina DOT (SCDOT) has experimented with a full-depth pavement reconstruction method using a single, thick lift of asphalt. The method includes milling the existing distressed pavement to depths of 4 or 5 inches and constructing a new inlay in a single pass. While this approach has been successful at these depths, SCDOT is interested in using even thicker mill and inlays. Key questions regarding compaction, mat cooling, and long term performance of extra thick lifts will be answered with their section, S9, which is a 7-inch thick single lift section. The section was instrumented during construction with pressure plates and strain gauges to measure long-term structural response of the section. During paving, the section was also monitored with embedded thermocouples to measure in situ temperatures and thermal imaging to capture surface cooling.

Texas DOT: Sections S10, S11
The Texas Department of Transportation (TxDOT) recently developed a special specification for balanced mix design that uses the Hamburg wheel tracking test to evaluate mixture resistance to rutting and moisture damage and the overlay test for assessing cracking resistance. Their objective is to compare the field performance of asphalt mixes designed using their balanced mix design approach (Section S10) versus the Superpave volumetric approach (Section S11) under accelerated loading conditions.

Both sections were constructed as 2-inch mill-and-inlays. The two mixes are similar in many respects; both have 20% RAP binder replacement, 0.5% liquid antistrip additive, and 9.5 mm NMAS with similar gradations. The primary difference is that the balanced mix design has a 5.5% total binder content, which is 0.5% higher than that of the volumetric control mixture (5.0%).

United Soybean Board: Section W10
The United Soybean Board has been sponsoring research at Iowa State University to develop a biopolymer derived from soybean oil. To bring this product closer to adoption, a new experiment is being carried out in this research cycle to evaluate a surface mix produced with a PG 76-22 asphalt binder that has been modified with the biopolymer. The field performance of this experimental mix in Section W10 will be compared with that of another surface mix in Section E5, which was produced with a conventional polymer modified PG 76-22 asphalt binder, to determine the effect of the biopolymer. Except for the two different asphalt binders, both mixes were produced based on the same 12.5-mm NMAS mix design with 20% RAP and paved as 1-3/4-inch mill-and-inlays.

West Virginia DOT: Sections W3, W4
The West Virginia DOT is a new sponsor on the Test Track and has funded an experiment to help determine an appropriate limit for the amount of dolomite in surface
mixes that will provide good friction characteristics. The experiment includes a laboratory study of mixtures with increasing amounts of dolomite from 50 percent to 100 percent of the dominant coarse aggregate for friction. The experimental mixtures on the two test sections have 70 percent and 90 percent dolomite coarse aggregate. Based on previous friction studies involving the Track and NCAT lab accelerated friction protocol, the experiment should give WVDOT a sound correlation for selecting an appropriate amount of dolomite for surface mixtures.

The Test Track sections were constructed as common 2-inch mill and inlay of a 3/8-inch NMAS mix using all WV common aggregate sources for dolomite, sandstone, limestone, and RAP. The direct substitution of dolomite for sandstone kept the volumetric properties and field density similar and close to mix design targets.

**Ongoing Research**
Several test sections built in previous cycles will also continue to be evaluated through the seventh cycle of the Test Track. Seven test sections built in 2015 for the Cracking Group Experiment will continue to be evaluated with additional traffic and environmental exposure. The objective of the Cracking Group Experiment is to validate laboratory tests suitable for routine use in mix design and quality assurance testing. It is an experiment being conducted in partnership with MnROAD where the NCAT Test Track sections are focused on top-down cracking and the Minnesota test sections are focused on thermal cracking.

The Virginia DOT is funding the continued evaluation of two test sections built in 2012. One test section features a 4.5-inch cold-central plant recycling (CCPR) base layer below four inches of asphalt concrete. The other section features an 8-inch cement stabilized sub-base, the CCPR base layer, and 4 inches of asphalt concrete.

The Alabama DOT is funding the continued evaluation of three experimental porous friction course (PFC) test sections also built in 2012. One section is a 9.5 mm NMAS PFC, and the other two are 12.5 mm NMAS PFC mixtures. The 9.5 mm NMAS mix contains 0.3% cellulose fiber to prevent drain-down. One of the 12.5 mm NMAS PFC mixes contains 0.05% synthetic fiber and the other contains 12% ground tire rubber.

The Kentucky Transportation Cabinet is funding the continuation of an experiment to evaluate the performance of Superpave surface mixes for longitudinal joint performance and durability. The experiment contains two subsections, one using a conventional coarse-graded Superpave mix, and the other using a fine-graded, lower-gyration mix design. The surface layers were constructed in both the inside and outside lanes of the Test Track to specifically evaluate longitudinal joint performance of the mix variations.

The Florida DOT is funding the continued evaluation of an experiment with four surface mixes containing 20 to 30% RAP. The Superpave mixes were 9.5 mm NMAS gradations and all used the same aggregate and RAP. The first three mixes contain a PG 76-22 SBS modified binder with 20, 25, and 30% RAP, respectively. The fourth mix contains a PG 67-28 SBS modified binder and 30% RAP.

Collaborative Aggregates is funding the continued evaluation of the surface mix containing their bio-based Delta S rejuvenator and 35% RAP. The test section was built in 2018 and is being compared to the 20% RAP control test section in the Cracking Group experiment.

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NCAT employees and students shoveled over 1000 buckets of asphalt mix during construction for laboratory testing.

**New Cycle. New Look.**
Visit our new website at http://ncat.us/testtrack for more information about the NCAT Test Track.
Study Examines Mixes Combining RAS and WMA

Annual surveys by the National Asphalt Pavement Association have shown that the use of recycled asphalt shingles (RAS) in asphalt mixtures peaked in 2013 and has since declined sharply. The surveys also show that the national average of reclaimed asphalt pavement (RAP) content has essentially plateaued at about 20% in recent years. The motivations to use RAP and RAS have largely been driven by interests in the conservation of natural resources and potential economic savings by reducing the quantity of new binder needed in mixtures.

The introduction and growth of warm mix asphalt (WMA) technologies over the past decade have provided additional opportunities to reduce energy consumption and emissions in asphalt pavement construction. However, the convergence of RAS and WMA has raised some concerns. Since RAS binders have very high softening points, some experts in the industry have questioned if lower mix temperatures with WMA are sufficient to activate hard RAS binders.

Earlier this year, NCAT completed a study under the National Cooperative Highway Research Program (NCHRP) to quantify the effects of RAS on asphalt mixture properties and evaluate the short-term performance of asphalt mixtures that used RAS in conjunction with WMA. The final report for this project is soon to be released as NCHRP Research Report 890.

The study included an extensive evaluation of mixtures from eight field projects that contained RAS produced at HMA and WMA temperatures. Laboratory performance tests were conducted to evaluate the recovered binders, mixture stiffness over a wide temperature range, moisture susceptibility, fatigue cracking, thermal cracking, and permanent deformation. Statistical analysis of the test results found no detrimental effects associated with using WMA technologies with mixtures containing RAS. As might be expected, laboratory tests showed that using WMA technologies improves the cracking resistance of some RAS mixtures.

Based on the literature review and research conducted at NCAT, no clear method has been identified to determine the degree to which RAS binder activates and becomes an integral part of the composite binder in an asphalt mixture. Some evidence indicates that at least partial activation of the RAS binder increases with higher mixing temperatures and longer mixture storage time. However, increasing the mixing temperature to better activate RAS binder results in increased mix stiffness and negatively affects a mixture's cracking resistance. Other factors that are likely to affect the degree of activation include the stiffness of the RAS binder, sizes of the RAS particles, chemical properties of the virgin binder and/or rejuvenator or other additives, mixing time, and storage time. It is unwise to assume that all RAS mixtures would have the same amount of activation under the range of conditions that exist in the real world.

A practical outcome of the project is commentary on recent revisions to AASHTO PP 78 that expands its application to WMA/RAS mixtures. The latest Provisional Standard Practice for Design Considerations When Using Reclaimed Asphalt Shingles (RAS) in Asphalt Mixtures (AASHTO PP 78-17) provided new guidance on determining the shingle aggregate gradation and specific gravity, adjusting VMA requirements, and testing of the composite binder for embrittlement using the critical low-temperature difference parameter $\Delta T_c$, as well as notes for the mix designer to consider. One new note states that “[a] mixture performance test for cracking implemented by the agency is acceptable in lieu of the binder testing for $\Delta T_c$.”

The study also examined the economics of using RAS. The use of RAS is most economically favorable when contractors are able to maximize tipping fees and use higher percentages of RAS when RAP contents are not impacted and when virgin asphalt prices are relatively high. Highway agencies are more likely to realize an economic benefit when competition among contractors is good and the performance of mixtures containing RAS is equal to or better than mixtures without RAS.

The report also includes recommended best practices for RAS processing. Lower mix production temperatures associated with WMA did not cause any plant issues or construction problems for any of the projects evaluated in this study. There were no problems with burners, baghouses, motor amperages, or mix storage. Excellent mixture coating was achieved with all WMA technologies at the lower mixture production temperatures. Roadway performance of HMA and WMA mixtures containing RAS after two to three years was practically the same. It was recommended that the field projects be reexamined in a few years so that the performance can be compared to the lab test results to aid in setting criteria for the mixture performance tests.
Framework for Balanced Mix Design

The Superpave mix design system was originally intended to include performance testing in addition to volumetric design for moderate and high traffic level pavements. However, the proposed tests for rutting and cracking resistance were not practical for routine use and were never implemented. During the early days of Superpave implementation, rutting resistance was the primary focus, prompting changes such as increased compactive effort, stiffer binders, and more angular aggregates. Many states also added testing requirements for the Asphalt Pavement Analyzer (APA) or the Hamburg Wheel-Tracking Test (HWTT). Today, most states indicate that rutting has been virtually eliminated and that various forms of cracking are now the controlling factors in asphalt pavement service life. Construction quality issues and failure to address underlying pavement distress can contribute to increased cracking. However, issues related to laboratory compactive efforts, aggregate specific gravity measurements, and the increased use of recycled and innovative materials, which cannot be fully assessed with volumetric mix designs, are also believed to contribute to cracking. Many highway agencies and contractors are contemplating a new era of mix design and quality assurance using mixture performance tests to improve asphalt pavement performance.

Balanced mix design (BMD) is an alternative method of designing asphalt mixes using performance tests on appropriately conditioned specimens to address multiple modes of distress while considering mix aging, traffic, climate, and location within the pavement structure. With BMD, mixes are designed to achieve a balance between rutting and cracking resistance using practical mixture performance tests. The BMD concept was initially developed at the Texas A&M Transportation Institute (TTI) using the HWTT and the Overlay Test (OT) to evaluate rutting and cracking resistance, respectively. Performance test results were used in addition to traditional volumetric criteria to determine the design asphalt binder content and grade that provided satisfactory resistance to both rutting and load-associated cracking.

NCAT recently completed NCHRP Project 20-07/Task 406, with the objective of developing a framework to address alternate approaches for BMD. Existing knowledge gaps were also identified, allowing research problem statements (RPSs) to be developed for future research that will help facilitate BMD implementation.

As part of the NCHRP project, NCAT conducted a survey of state DOTs regarding the current use of performance testing and BMD practices. Of the 47 states that responded, six already use BMD. Iowa, Illinois, Louisiana, New Jersey, Texas, and California all use some form of BMD, but the performance tests, criteria, and adherence to Superpave volumetric criteria differ among these DOTs. Many other DOTs require a single performance test in their mix design specifications but are not using a “true” BMD approach, which the FHWA Task Force on BMD defined as addressing multiple modes of distress. A majority of states showed interest in constructing BMD trial projects to compare performance with mixes designed using volumetric criteria alone.

Based on the survey results and a literature review, NCAT developed a framework for BMD in the form of a draft AASHTO standard practice and standard specification. Agencies may select the performance tests of their choice for rutting resistance, cracking resistance, and moisture susceptibility. Existing criteria used by different state DOTs are given in the draft standard specification. The draft standard practice includes four BMD approaches. Approach A, Volumetric Design with Performance Verification, is more restrictive than AASHTO R 35 in that the completed Superpave mix design must meet the additional performance test requirements. Approach B, Volumetric Design with Performance Optimization, allows adjustment of the optimum AC by ±0.5% to meet performance test criteria. Approach C, Performance-Modified Volumetric Design, uses AASHTO R 35 through the evaluation of trial blends, at which point performance testing is conducted to determine optimum AC. In Approach C, the agency may relax some of the volumetric criteria in AASHTO M 323 provided that performance test criteria are met. Approach D, Performance Design, relies entirely on performance test results to select all mix component proportions. This approach is the least restrictive, allowing the highest level of innovation.

The centerpiece of BMD is performance testing to evaluate mix resistance to rutting and cracking. Cracking tests can be further categorized by the mechanism involved in crack initiation and propagation: thermal cracking, reflective cracking, bottom-up fatigue cracking, and top-down fatigue cracking. Most states currently require the testing of mix resistance to moisture damage, another common distress of asphalt pavements. Perhaps the biggest question for implementing BMD is: what are the “best” performance tests for each type of distress?
Numerous tests have been developed over the past few decades. Some are better suited for routine use in mix design and quality assurance, while others are primarily focused on characterizing the fundamental properties of a mix to predict pavement response. For a performance test to be included in BMD procedures, criteria must first be established based on good correlations between laboratory and field performance. Other practical considerations include testing time, complexity of data analysis, test result variability, cost and availability of equipment, and sensitivity to mix parameters. Another primary concern is establishing appropriate mix conditioning and aging protocols for performance tests.

Many DOTs and contractors recognize the benefits of BMD and are working toward implementation. However, gaps still exist in the knowledge needed to reach full implementation. NCAT researchers identified nine important steps necessary for moving a test method from concept to implementation and conducted an extensive literature review to determine which steps have been completed for candidate test methods in each distress category. This process allowed the research team to identify existing knowledge gaps and test development steps needed to advance the most promising test methods into mainstream practice. Each distress category is summarized below.

**Thermal Cracking**
There are six candidate tests for this distress mode, including the Low-Temperature Semi-Circular Bend Test (SCB), the Disk-Shaped Compact Tension Test (DCT), and the Illinois Flexibility Index Test (I-FIT). A comprehensive sensitivity study is needed to evaluate the top three candidate tests. DCT has more critical steps completed than the others and seems to be the most preferred test based on survey responses and existing literature. If two major ongoing studies have positive results, the research needs for implementation of the DCT should be complete; the only additional need is training for other states that plan to implement it. Lower-priority needs are conducting round-robin testing and training for the low-temperature SCB test.

**Reflective Cracking**
Five candidate tests are included for this distress mode. Based on survey results and the literature review, OT and DCT appear to have the most potential for evaluating resistance to reflective cracking and have completed more critical steps required for implementation than other candidate tests. If several ongoing studies provide positive outcomes, only robust field validation and training would be needed for implementation of these two tests. The SCB-Jc and Flexural Bending Beam Fatigue Test (BBF) are not recommended for implementation because multiple critical steps are incomplete; furthermore, the BBF test is considered impractical for routine use.

**Bottom-Up Fatigue Cracking**
There are six candidate tests for this distress mode, including the BBF, SCB-Jc, OT, and I-FIT. OT and I-FIT appear to be the top candidates for BMD implementation. For both tests, a robust validation experiment to set test criteria for bottom-up fatigue cracking is the largest knowledge gap. Although research is ongoing to validate these tests for other modes of cracking, no validation experiments are planned for bottom-up fatigue cracking. This is a lower-priority research need for several reasons. First, most asphalt tonnage in the U.S. is produced for rehabilitation of existing pavements rather than new construction, where bottom-up fatigue cracking would be a design consideration. Second, the use of a valid perpetual pavement design strategy could eliminate bottom-up fatigue cracking as a mode of pavement failure for new asphalt pavements.

**Top-Down Cracking**
Five test methods are candidates for this mode of distress. I-FIT appears to have the most potential for BMD implementation since all nine critical steps have been completed or are ongoing. Another promising candidate is the Indirect Tensile Asphalt Cracking Test (IDEAL-CT), a relatively new test developed at TTI. Several critical steps still need to be addressed, but the IDEAL-CT’s primary advantage is that specimens do not require cutting, notching, or gluing, making the test method much faster than any other cracking test.

**Rutting**
There are five candidate test methods for rutting resistance, including the HWTT and APA, which are already used by numerous state DOTs. All critical steps have been completed for the HWTT, and the only gap for the APA is a round robin study. Most steps have also been completed for the Flow Number Test (FN), but no states have implemented it for routine use as a rutting performance test.

**Moisture Susceptibility**
The HWTT and Tensile Strength Ratio (TSR) are most commonly used to evaluate resistance to moisture damage. However, there is serious concern that test results may not be reliable indicators of field performance. Thus, a robust validation experiment is needed to evaluate both test methods for reliability.
Based on the survey results, the top five distresses that agencies wish to address with performance testing are fatigue cracking, rutting, thermal cracking, moisture damage, and reflective cracking. This ranking was used as a guide, along with the literature review and analysis of knowledge gaps, to establish priorities for research needed to facilitate BMD implementation. The following nine research problem statements (RPSs) were developed to aid continued advancement of BMD. Detailed descriptions of each project, as well as cost estimates and suggested schedules of completion, are found in Appendix B of the report for NCHRP Project 20-07/Task 406.

1. Laboratory aging protocols for cracking tests
2. Validation of reflective cracking tests
3. Further validation of top-down cracking tests
4. Validation of moisture susceptibility tests
5. Refinement of AASHTO T 324 (HWTT)
6. Establishing precision estimates for AASHTO T 340 (APA)
7. Validation of bottom-up fatigue cracking tests
8. Sensitivity of thermal cracking tests to mix design variables
9. Establishing precision estimates for AASHTO TP 105 (Low-Temperature SCB)

The ongoing NCAT/MnROAD Cracking Group Experiment will contribute to the validation of top-down and thermal cracking tests by correlating laboratory results with field measurements. Findings will help agencies select the most suitable cracking tests for BMD as well as provide preliminary test criteria. Additional BMD-focused research is ongoing at the NCAT Test Track, with the placement of four test sections sponsored by Oklahoma and Texas in the 2018 research cycle.

NCAT offers a Balanced Mix Design Course, which is a 2 1/2-day workshop that provides hands-on training with all laboratory performance tests used in BMD. Attendees also gain a better understanding of the BMD process. Upcoming course dates are February 5-7, 2019.
Evaluation of the Regressed Air Voids Approach for Mix Design

The Wisconsin Department of Transportation (WisDOT) is working to improve pavement durability and cracking resistance by increasing the amount of binder in their asphalt mixtures. In the last few years, they implemented an approach referred to as “regressed air voids” for the design of all asphalt mixes. The concept of regressed air voids is to design a mix for the current practice of 4.0% air voids and satisfy all other Superpave criteria, then determine how much additional virgin asphalt binder is needed to achieve an air void target of 3.5% or 3.0%.

NCAT recently completed a study for the Wisconsin Highway Research Program to evaluate the impact of regressed air voids on cracking, rutting, and moisture damage resistance of asphalt mixtures. The objective of the research was to assess the impacts of increasing asphalt binder contents of mixtures designed using the regressed air voids concept and to recommend whether or not to proceed with implementation of this approach.

The study evaluated mixtures from each of WisDOT’s three traffic categories. The research panel advised NCAT researchers on selection of the initial mix designs and mixture performance tests for the laboratory experiment. Testing included six primary mixes designed for low, medium, and high traffic levels and containing various amounts of reclaimed asphalt pavement (RAP) and recycled asphalt shingles (RAS). After verifying the primary mix designs at 4.0% air voids, variations of each mix were tested at asphalt contents corresponding to 4.0, 3.5, and 3.0% air voids. Mixture performance tests included the Illinois Flexibility Index Test (I-FIT) per AASHTO TP 124 to evaluate intermediate temperature cracking resistance, the Disk-Shaped Compact Tension (DCT) Test per ASTM D 7313 to evaluate low temperature cracking resistance, and the Hamburg Wheel Tracking Test (HWTT) per AASHTO T 324 to evaluate rutting and moisture damage resistance.

For five of the six mixtures evaluated, regressing the design air voids to 3.0% air voids increased the asphalt contents by 0.3 to 0.4% and resulted in a clear improvement in the flexibility index. Based on these results, the regressed air voids approach to mix design has a positive impact on the intermediate temperature cracking resistance of asphalt mixtures.

Although DCT Fracture Energy results also increased for mixtures regressed to 3.0% air voids, the improvement was not statistically significant. Based on these results, the regressed air voids approach is not expected to have a significant impact on thermal cracking.

Hamburg results analyzed using the AASHTO procedure indicated that two of the mixes were susceptible to moisture damage. However, field performance of these mixtures has not shown any indications of stripping. This could indicate that the Hamburg test can give false positive errors. None of the six mixtures exhibited stripping inflection points in the first 10,000 passes of the test. The four mixes that had no signs of stripping completed the full 20,000 passes with rut depths less than 12.5 mm. Corrected rut depths using a modified method of analysis were significantly lower than the common maximum rutting criterion of 12.5 mm. All of the mixtures designed to 3.0% regressed air voids met the rutting criterion, indicating that the regressed air voids approach would not likely cause a problem with increased rutting susceptibility of asphalt pavements.

Many asphalt technologists understand that only adjusting the air void target may not be sufficient to optimize mix designs and ensure that they will perform as desired. Consequently, the concept of balanced mix design is gaining popularity as a way to better assess a mix design’s resistance to major forms of distress, including rutting, cracking, and moisture damage.

In a balanced mix design framework, a performance diagram can be a useful tool to examine the balance between the rutting and cracking susceptibility of an asphalt mixture. Using such a diagram, a cracking parameter is plotted against a rutting parameter to assess the interaction between the two as the asphalt content of the mix (or other mix variable) is changed. In this case, the I-FIT flexibility index (FI) was plotted against the corrected rut depths from the Hamburg test. Figures 1 through 3 show performance diagrams for the low, medium, and high traffic Wisconsin mixes, respectively.

For the majority of the mixtures, there is a significant increase in flexibility index (vertical axis) due to higher asphalt contents resulting from the regressed air voids approach, but the change in rutting resistance (horizontal axis) was not much, and all mixes easily met a common criteria of 12.5 mm in the Hamburg test. Comparing the performance diagrams reveals that the high traffic category mixes (designed to higher Ndesign levels) shift toward the lower left part of the diagrams. It makes sense that the higher gyration mixes are more rut resistant and that they are generally going to give up some cracking resistance. The important questions are:
how much cracking resistance should be sacrificed and how much rutting resistance is enough?

Results from this project indicate that the regressed air voids concept can improve cracking resistance without compromising the deformation resistance of asphalt mixes. Therefore, a three-stage implementation strategy was recommended: (1) full implementation of the 3.0% regressed air voids mix designs without performance tests, (2) continued use of the 3.0% regressed air voids mix designs with added Hamburg rutting and stripping criteria based on traffic levels, and (3) implementation of balanced mix design and eventually withdrawing the regressed air voids design requirement and other volumetric criteria for mix design approval.

Figure 1. Performance Diagram of I-FIT FI versus Corrected Hamburg Rut Depth for Low Traffic Mixes

Figure 2. Performance Diagram of I-FIT FI versus Corrected Hamburg Rut Depth for Medium Traffic Mixes

Figure 3. Performance Diagram of I-FIT FI versus Corrected Hamburg Rut Depth for High Traffic Mixes
Initial Service Life Determination in Life Cycle Cost Analysis

Highway agencies often use life cycle cost analysis (LCCA) to select the most cost-effective alternative when planning new construction or reconstruction of a roadway. A key input in an LCCA is the service life, also known as performance period, of the pavement alternatives. Most agencies use different service lives for initial construction and rehabilitation activities. The initial service life represents the average number of years for a newly constructed or reconstructed pavement to reach the agency’s threshold for rehabilitation. The rehabilitation performance period is the length of time for a rehabilitated pavement to reach the agency’s rehabilitation threshold.

The initial performance periods can be significantly different for competing pavement alternatives. The timing of future maintenance and rehabilitation activities have an effect on the life cycle cost of each pavement alternative. Therefore, an important question for agencies conducting LCCA is: what is the actual initial service life for each pavement type? The National Asphalt Pavement Association and the State Asphalt Pavement Associations recently sponsored research at NCAT to answer this question. The objectives for this study included: (1) reviewing the methods that DOTs currently use to set initial service lives for both asphalt and concrete pavements, (2) determining actual service lives based on the age of the pavements at first rehabilitation using historical data, and (3) determining the pavement ride quality at the time of first rehabilitation.

A literature search and a survey of state DOTs were conducted to gather information about pavement service lives and rehabilitation activities considered in LCCA for both asphalt concrete (AC) and portland cement concrete (PCC) pavements. Long-term Pavement Performance (LTPP) program data were analyzed to determine the actual timing of first rehabilitation of AC and PCC pavements and the ride quality based on International Roughness Index (IRI) at the first rehabilitation for pavement sections in the U.S. and Canada.

The initial performance periods used in LCCA by the majority of agencies ranged between 10 and 15 years for AC pavements and between 20 and 25 years for PCC pavements. A common method agencies use to determine pavement performance periods was found to be the utilization of historical data from their state pavement management system (PMS). Other methods reported included using expert opinions, engineering judgement, and the pavement design life.

State DOT practices for determining the actual timing of rehabilitations for both AC and PCC pavements are unique to each agency and often include various pavement condition indices. The individual distresses reported to be part of the indices were typically cracking, IRI, and rutting for flexible pavements, and cracking, IRI, and faulting for rigid pavements. While cracking was reported for both pavement types, cracking is not quantified in the same way across all pavement types and cannot be compared directly. Given the difference in distress types and cracking definitions for each pavement, condition indices and associated thresholds are not comparable between unlike pavement types. Therefore, actual practices and criteria for determining timing of rehabilitations may not be based on equal levels of performance.

However, IRI is a common performance measure used in most decision-making processes for determining the actual timing of rehabilitation. Some agencies have threshold values associated with IRI, but they vary widely from state to state. Therefore, a nationwide consensus among DOTs does not exist for IRI values that indicate the need for pavement rehabilitation.

Data from the LTPP General Pavement Study (GPS) experiments and in the Specific Pavement Study (SPS) experiments were examined to determine the timing of the first rehabilitation events. This database includes AC and PCC pavements. Initial service lives for all sections were determined based on the dates of the first rehabilitation activity and the original construction reported in the LTPP database.

The first rehabilitation activity used by DOTs differs among pavement types, with diamond grinding being the most common for PCC pavements, and mill and inlay as the most common for AC pavements. From the analysis of the LTPP data, the average asphalt pavement age at time of first rehabilitation was found to be approximately 18 years (Table 1). This is much longer than the 10 to 15 years for the initial performance periods currently used by most DOTs for LCCAs. For concrete pavements, the LTPP data shows that the age at first rehabilitation is about 24 years (Table 1). This is consistent with the survey responses of what DOTs are using for initial performance period in LCCAs.
The mean roughness index (MRI) values (the average of the left and right wheelpath IRI measurements) measured just prior to the first rehabilitation were also examined from the LTPP database. The MRI values for the pavement sections were compared to the FHWA categories for ride quality (very good, good, fair, poor, and very poor) associated with IRI measurements (Table 2). In general, AC pavements were smoother than PCC pavements at the time of rehabilitation. AC pavements were most often rehabilitated while in good or fair ride quality, while PCC pavements were rehabilitated in fair or poor ride quality. For both AC and PCC pavements, more than 85% of the pavement sections were rehabilitated before reaching the threshold of 170 in/mile for the very poor category. Given this high percentage, an MRI of 170 in/mi is too high to be used as a first rehabilitation trigger.

As shown in Table 3, the 95% confidence intervals of both pavement types overlap between 119 in/mi and 121 in/mi, which corresponds with the early FHWA threshold of 120 in/mi dividing fair and poor ride quality. Thus, an MRI value of 120 in/mi should be considered a functional performance threshold to determine initial performance periods of AC and PCC pavements for use in LCCA.

This study recommends using MRI, the performance measure common to all pavement types, for determining initial service lives for LCCA to ensure consistent levels of performance are being compared among unlike pavement types. A functional performance threshold of 120 in/mi is recommended since this value represents the separation of fair and poor ride quality.

The study also found that most highway agencies currently use initial performance periods for asphalt pavements that are much lower than the actual age at time of first rehabilitation based on national LTPP data. Given the ongoing advancements in materials, pavement design, and construction, the pavement initial service lives used in LCCA should be re-examined periodically to ensure they are representative of actual performance.
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An online application should be completed at least 60 days before the semester starts. Additional submissions are required, including a statement of purpose, three letters of recommendation, GRE scores, and college transcripts. Non-degree applicants must submit an application and official transcript showing the highest degree earned. For more information, visit http://eng.auburn.edu/online/graduate-programs/index.html.
Where Are They Now?

Many former NCAT students have benefited from the connections they made while at Auburn and continue to collaborate with the asphalt community. In this issue, we catch up with Mark Buncher, Jay Gabrielson, and Jamie Green to learn more about their journeys since graduation.

Mark Buncher
Dr. Mark Buncher was provided the opportunity to obtain a Ph.D. in Civil Engineering specializing in pavements while serving our country as an active duty Air Force serviceman. He began studying at Auburn in 1992, and after spending many days and nights in the NCAT lab he was awarded his doctorate in 1995.

Mark currently serves as the Director of Engineering for the Asphalt Institute in Lexington, Kentucky. The Institute’s mission is to serve both users and producers of asphalt materials by advancing technology and improving pavement performance through programs of education, engineering, and research.

“I’ve always had the utmost respect for NCAT starting from when I was part of the NCAT family and up through the present,” said Mark. “Auburn was a great location to bring my family with lots of other young families and many activities offered through the university. I’m eternally grateful for my time there, all of the experiences and knowledge learned, and foremost for all the wonderful friendships that started there. So many of those friends are in the asphalt industry today; too many to name.”

He and Cathy, his wife of thirty-five years, have seven children and five grandchildren. They enjoy spending time outdoors hiking and biking and have recently begun Orange Theory Fitness. They are fans of SEC sports and enjoy following the University of Kentucky football and basketball teams.
Asphalt Technology News

Jay Gabrielson
Dr. Jay Gabrielson began his doctoral studies at Auburn University in 1990 researching the permanent deformation of hot mix asphalt at NCAT. After graduating in 1992, he joined the Vulcan Materials Company where he has worked for the last 25 years. Jay is currently the Director of Technical Services for Vulcan’s Central Division where they produce crushed stone from approximately 80 quarries and produce and place hot mix asphalt from plants located throughout middle Tennessee.

“Auburn and NCAT were a great match for me because of the balanced blend of research and practice,” said Jay. “It wasn’t just about the research; it was about the work ethic, the leadership, and practical application of engineering principles into pavement structures. I tip my hat to the NCAT staff and Dr. Frazier Parker, my Civil Engineering professor, for their approach to research, problem solving, and keeping the graduate students grounded. They molded us into productive asphalt citizens. Even now, twenty-five years later, I’m still the student as I continue to reach out to those people who molded me in the early nineties.”

He and his wife, Elsie, live in Knoxville, Tennessee with their children, Sydney, Keith, and Reese. Sydney is a junior at the University of Alabama, Keith is a sophomore at Princeton University, and Reese is enjoying life as a tenth grader. The Gabrielson family enjoys spending time together at the lake, traveling, and working on projects at home.

NCAT’S laboratory is AASHTO-accredited and can provide independent performance testing for a nominal fee.

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- Tensile Strength Ratio (TSR)
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- Hamburg Wheel-Track Testing
- Asphalt Pavement Analyzer (APA)
- Flow Number
- Dynamic Modulus (E*)
- Resilient Modulus (Mr)
- Overlay Test
- Illinois Flexibility Index Test (I-FIT)

Contact NCAT Lab Manager Jason Moore at 334-844-7336 or moore02@auburn.edu.
Jamie Greene

Jamie Greene earned both his bachelor’s and master’s degrees in civil engineering from Auburn University. He began working at NCAT in 1994 as a part-time student and eventually transitioned to a full-time engineer when he graduated with his bachelor’s in 1997. In addition to regular lab work, Jamie assisted with some of NCAT’s contractor and professor training courses.

After graduating with a master’s in 1999, Jamie worked for Applied Research Associates under contracts with the Air Force Research Laboratory at Tyndall Air Force Base in Florida through 2003, and then under another contract with the Florida Department of Transportation (FDOT).

“I started working for FDOT in 2008 as a pavement research engineer managing FDOT’s Accelerated Pavement Testing program,” said Jamie. “I now work as a pavement evaluation engineer and manage FDOT’s network and project level pavement condition monitoring program. We sponsor test sections at NCAT, so I’m still routinely working with some of the Test Track staff such as Buzz Powell and Dave Timm.”

Jamie has lived in Gainesville, Florida since 2003 and has been married for 11 years. He and his wife enjoy taking road trips, hiking, and spending time at the beach. They recently bought a ‘fixer upper’ house, which keeps him busy most weekends.

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**Specification Corner**

**Colorado DOT**

Colorado Procedure 52 (Contractor Asphalt Mix Design Approval Procedures) was revised to add a note that "the RAP aggregate bulk specific gravity will be back-calculated using an assumed average aggregate water absorption of 1.01%. The corresponding assumed aggregate asphalt absorption will be 0.61%." This revision is in line with AASHTO R 35.

**Florida DOT**

In January 2019, a Delta $T_c$ requirement will be added to the FDOT asphalt binder specification. Asphalt binders aged with the PAV for 20 hours must have a Delta $T_c$ greater than or equal to -5.0°C. Also, REOBs/VTAEs will be limited to 8.0% max.

**Massachusetts DOT**

Starting in 2019, MassDOT intends to standardize its HMA QA specification (Section 450) from the standard special provision, which has been used for the last 10 years.

**Utah DOT**

Utah added a longitudinal joint density specification for hot mix asphalt paving and has noticed good results with it so far. The longitudinal joint target density is 91.5% of Gmm with a lower limit of 89.5%. Six-inch cores on the joint every 1000 feet are tested.

Utah changed its micro-surfacing specification to use only natural or synthetic latex for the polymer. A requirement of 3% by weight of the binder has not changed. Utah is getting good results, and the projects look great so far.

Utah removed the Direct Tension Test (DTT) for modified binders for all projects next year because of the cost, availability, and service of the equipment. The test has been replaced with the Delta $T_c$ parameter of -1.0°C for one PAV cycle with a compliance limit down to -2.0°C and a minimum stiffness on the first Bending Beam Rheometer (BBR) beam of 300 MPa. Elastic recovery requirements have also been increased. These changes were made to give us the same binders we currently have with the use of the DTT. We believe the DTT has kept REOBs out of our market.
Asphalt Forum

NCAT invites your comments and questions, which may be submitted to Christine Hall at christine@auburn.edu. Questions and responses are published with editing for consistency and space limitations.

With the development of the regressed air void concept, balanced mix designs, and greater emphasis on higher field densities, the asphalt pavement community seems to be more comfortable with mixes designed to have less than the 4.0% air void target traditionally used for Superpave design. What is the minimum air void level for in-place compacted pavements at which the mix would not be acceptable for your organization?

-Don Watson, NCAT

Asphalt Forum Responses

The following responses have been received to questions shared in the previous issue.

How do states deal with quality assurance (QA) testing of asphalt pavements as opposed to contractor quality control (QC)? In Montana, we have a long standing internal argument about requiring QC testing from the Contractor. Our solution is to craft our specifications to force QC. In reality, our contractors are using the state's QA results for their QC because "that's what they get paid on." This causes issues when test results aren't returned ASAP, if there are math errors, etc. I'm wondering if any other DOTs use this process or does everyone else keep QA and QC separate?

-Oak Metcalfe, Montana DOT

Michael Stanford, Colorado DOT
CDOT keeps QA and QC separate.

Greg Sholar, Florida DOT
In the early 2000s, we adopted a system where payment is based on verified QC tests. There are several layers of checking involved, but in short, FDOT tests a random split sample of the QC sample on a frequency of one FDOT test per four QC tests. If the QC test is verified, then payment is based on QC test results. If it isn't verified, then it gets a little bit more complicated and there isn't enough space here to explain. In addition, each district lab performs independent verification testing to assess the quality of the material. Prior to this approach, FDOT used to operate like Montana, where FDOT's test was used for payment, and we had the same sentiments from contractors.

Bryan Engstrom, Massachusetts DOT
We have a QA specification (Section 450) that requires both DOT acceptance testing and Contractor QC. Based on project tonnage, QC results may also be used as part of acceptance. QC results are required to be reported within 24 hours of testing in order to be used in payment determination.

Eric Biehl, Ohio DOT
Ohio requires contractors to perform QC much more frequently than we do QA. QC testing is required at least once every half-day. We will typically test one of the splits (if not more) at a frequency of 1 in 4 production days. Depending on the acceptance, there are more samples taken. We do deduct or remove and replace if the contractor has poor QC results or if there are comparison issues.

Cliff Selkinghaus, South Carolina DOT
Our QA samples are the same as the contractor’s QC samples; the only significant difference is that our QA staff witnesses the sampling and testing from start to finish. Split samples of the QA samples are later tested by the department (compare favorably: yes/no) and the technician is checked off the list being a system based approach and not every project.

Matthew Chandler, Tennessee DOT
Each year, we require the asphalt plant to submit a QC plan with stated frequencies for testing. Most of this is left up to the contractor to define, but key checks are given at the required frequency, which includes them checking the tests we run for acceptance (AC% and gradations). Additionally, we have an inspector at the plant that runs independent acceptance testing in the contractor’s lab.

Howard J. Anderson, Utah DOT
We require the contractor to submit their QC testing in
any dispute resolution process. If the contractor does not do QC testing, they can't dispute any of our acceptance tests. We keep QC and QA tests separate.

Joe DeVol, Washington State DOT
WSDOT does not require contractor QC; we expect our contractors to perform their own QC rather than use our results for that purpose.

How do states address sand equivalent testing, and more specifically, batching specimens for testing? Do you batch from individual stockpiles or blends from cold feed? How do you address baghouse effects on the job mix formula? We don't have a state asphalt paving association in Montana, so we don't have standardized batching procedures yet; however, we will be publishing ours soon.

-Oak Metcalfe, Montana DOT

Michael Stanford, Colorado DOT
Sand equivalent testing is only required for fine aggregate used for concrete. The minimum SE, as tested in accordance with Colorado Procedure 37, shall be 80 unless otherwise specified. We typically batch cold feed. Baghouse effects are addressed on the job mix formula in the D/A requirements.

Greg Sholar, Florida DOT
We rarely test for sand equivalent anymore except for proficiency samples. However, in the earlier years of Superpave implementation, we tested every sand source used in mixtures. Those samples came from stockpiles.

Bryan Engstrom, Massachusetts DOT
MassDOT annually tests source samples from stockpiles in the beginning of the year. Currently, we do not perform any SE testing during production unless a question arises.

Eric Biehl, Ohio DOT
We only require sand equivalent testing for micro surfacing. We use fines to asphalt ratio to control dust in asphalt mixtures, which also handles baghouse effects.

Matthew Chandler, Tennessee DOT
We don't regularly use sand equivalency for HMA but do check it for micro surface. Mix design specimens are batches from stockpiles. Completed batch designs are extracted and gradations within tolerance are checked to verify that extra fines aren't excessive.

Howard J. Anderson, Utah DOT
We take our acceptance tests from behind the paver for HMA. For SMA and OGFC we take the samples from the trucks at the hot plant.

Joe DeVol, Washington State DOT
Our SE samples are taken directly from contractor's stockpiles. We do not address the effects of baghouse fines on the JMF; the contractor is required to meet the JMF as approved on the mix design.

What is your agency policy or specification regarding re-refined engine oil bottoms (REOB)? Are there limitations on the amount allowed, or are they banned completely?

-Greg Sholar, Florida DOT

Michael Stanford, Colorado DOT
702.01 of CDOT's Specification states "Asphalt Cement shall not contain any used oils that have not been re-refined." Beyond that, the AC must meet our specifications.

Bryan Engstrom, Massachusetts DOT
REOBs are completely banned in Massachusetts.

Eric Biehl, Ohio DOT
Per ODOT Construction and Material Specification 702.02, we allow up to 5.0% previously used material (REOB, etc.) but it must be approved by ODOT. No such material has been approved to date.

Cliff Selkinghaus, South Carolina DOT
We allow it but it must be disclosed in the supplier's QC plan. We do not use anything softer than a PG 64-22, so we have not seen any show up thus far. We also ask the suppliers to ensure their binders are compatible with any other additives like anti strips.

Matthew Chandler, Tennessee DOT
We do not have a specification requirement with regard to REOBs. We are assuming at -22 (low PG grade) there is little need to use them. We are actively utilizing an FTIR to fingerprint binders and analyze for heavy metals to identify if they are being used.

Howard J. Anderson, Utah DOT
We don't have any suppliers currently using REOB that we know of. We don't prohibit its use. According to our binder suppliers, the DTT test has limited its use in our state.

Joe DeVol, Washington State DOT
Washington State DOT does not have any policies or specifications that deal with REOBs in our asphalt binders.
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