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Features

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Contents

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Message from the Director

Another Perspective

Almost six years ago, I was in Japan for a "scan tour" to learn how they regularly use asphalt mixtures containing 50% or more recycled asphalt pavement. One day, our group took a break from asphalt technology and visited the Ryōan-ji temple and its famous Zen garden. The Zen garden is a rock garden about the size of a tennis court comprised mostly of carefully raked white gravel. Within this tranquil bed of gravel are fifteen large stones ranging in size from a loaf of bread to a buffalo. There are a number of interpretations about what the stones represent. Some suggest that the garden is merely meant to stimulate meditation. However, what I most remember was that not all 15 stones were visible from any single vantage point. Some of the stones were hidden behind others. If you moved to another point along the perimeter, you could then see those "hidden" stones, but then others were no longer in view. The inspiring lesson was that you must sometimes change your point of view to see the whole picture.

This is true for many of life's experiences. I've been fortunate in my career to work for a state DOT, a contractor, and a research organization. Each of these steps taught me to take different perspectives on the realities of building and maintaining public roads. Something I didn't appreciate when I worked for the highway agency was the real challenge of getting a mix design to meet the specifications with the available materials and then having to make adjustments in the mix to keep it within the specification limits during production. The realities of materials, sampling and testing variabilities were eye-opening when I began wearing a contractor's hat.

Recently, we hosted the National Balanced Mix Design Implementation Conference. The last part of the conference featured breakout sessions where participants were randomly assigned to small groups to discuss several critical issues related to balanced mix design implementation. Each person was given the chance to voice their views on the issues and then respond with a possible solution via a poll. In my closing comments to the conference, I asked everyone if their mind had been changed after hearing the perspectives of others in their group. Most people raised their hands.

Often, taking another perspective allows us to see the something that was not evident from where we first stood. It may not be an epiphany that's revealed in a Zen garden, but listening to and considering someone else's opinion will help us see the circumstances more fully.

Randy C. West, Ph.D., P.E.
NCAT Director and Research Professor

Eighth Test Track Cycle Focuses on Innovative Materials

Operations at the NCAT Test Track began in 2000 to improve materials, tests, specifications and design policies by providing sponsors confidence to move innovations into practice. The only high-speed, full-scale accelerated pavement testing facility of its kind, the 1.7-mile oval consists of test sections sponsored by U.S. highway agencies and the asphalt pavement construction industry. Now in its eighth three-year cycle of accelerated pavement research, the track will include new and continuing experiments to evaluate innovative additives, balanced mix design (BMD) trials for several states and pavement preservation research.

SURFACE PERFORMANCE SECTIONS

Surface mix performance sections are built on a robust cross-section that limits distresses to the experimental surface layers. Seven test sections on the track have been milled and inlaid with new mixtures to evaluate how they can stand up to the severe loads from the track's fleet of five trucks, each weighing in at 156,000 lbs.

Alabama DOT (E9)

Section E9 is a high-performance open-graded friction course (OGFC). The OGFC mixture was designed with a new method requiring gyratory compacted specimens to have air void contents between 15 and 20%, and less than 20% loss in the Cantabro test after four hours of aging at 275°F. To test the new design methodology, the OGFC mixtures incorporated aggregates with a history of marginal performance in Alabama.

Kentucky Transportation Cabinet (S7)

The experiment on S7 aims to establish a BMD+ approach for Kentucky surface mixes that will include popular BMD test criteria as well as provide good long-term friction performance with skid resistance values in the mid 30s and 40s. The experiment began with a laboratory evaluation of several mixes with Kentucky aggregates using NCAT's Three-Wheel Polishing device followed by periodic friction and surface texture measurements using the Dynamic Friction Tester and Circular Track Meter.

Aggregate traveling to the drum at East Alabama Paving in Opelika, Alabama.

The crew paves Kentucky's balanced mix design Section S7.

Tack coat is applied to North Carolina's Section W4 in the Test Track's west curve.

North Carolina DOT (W4)

The main goals of Section W4 are to investigate the effects of tack coat type and application rate on bond strength over time to assess the influence of aging and traffic loading. The experiment will also evaluate NCDOT's specifications regarding the shear stability of high recycled content mixes under high stress conditions. The research will help compare NCAT shear bond strength results to those performed in North Carolina and determine if the test is useful as a forensic tool for investigating projects with early distress.

Oklahoma DOT (N8, N9)

Section N8 is a mill and fill section with two layers providing a total thickness of 5 inches. The lower layer is the same mix used in the 2018 cycle as the intermediate layer in Section S1. The surface layer contains 30% reclaimed asphalt pavement (RAP) compared to a 15% RAP content in the surface layer of S1. Both layers were designed as BMD and used rejuvenators to treat the RAP. Strain gauges were installed at the bottom of N8-2 and pressure plates previously used in that section are being reused. The overall purpose of the experiment is to evaluate a recently developed rejuvenator with a substantially higher RAP content in the surface layer.

Oklahoma's Section N9 is compacted by a vibratory smooth drum roller.

Section N9 was built as a 1.5-inch mill/inlay using BMD and incorporated 12% recycled tire rubber (by mass of binder) added via the dry process during mix production. The aggregate structure is similar to the previous N9 surface mix that was BMD-optimized and placed at the same 1.5-inch thickness in 2018. In both cases, the perpetual pavement cross-section had a small amount of top-down cracking that extended below the depth of micro-milling. The objective of this research is to assess the performance of the rubber modified mix and its potential to resist reflection cracking from the underlying layer. Top-down and/or reflection cracking with the new rubber modified BMD mix will be compared to the previous conventional BMD mix to assess the impact of the recycled tire rubber on performance.

Assistant Research Engineer Grant Julian verifies mixture temperature for Section N6.

Tennessee DOT (S4)

Tennessee DOT has embarked on an important study to define the limits of their proposed BMD specification thresholds. Starting with a mix design that far surpassed TDOT's proposed BMD thresholds, the mix was "economized" by reducing virgin asphalt binder content, increasing RAP percentage and adjusting the gradation to lower the cracking test index to barely pass the threshold. Considering that TDOT is still a Marshall mix design state, the research team conducted the IDEAL-CT test on specimens prepared using the Marshall hammer to assess the viability of using the compactor for BMD testing. This mix design has been placed on Section S4 and will be monitored for performance throughout this research cycle.

Texas DOT (N6)

TxDOT is further expanding its efforts to validate their BMD criteria with a new test section to complement its other research on S10 and S11, described under "Continuing Experiments". The underlying pavement structure for N6 is similar to those in S10 and S11. The goal of the BMD mix for this new section was to use the same constituent materials that were used in S10 and S11 with a gradation that is between S10 and S11. Although the same aggregate sources and asphalt binder source and grade were available, another RAP material had to be located from the same area as the RAP used in S10 and S11. TxDOT also wanted to target a Texas Overlay test crack progression rate (aka β value) of 0.45 for the mix in this test section to help define the threshold for their BMD specifications. NCAT successfully designed the mix meeting all of the goals, and the new BMD mix was placed on N6 for field validation.

STRUCTURAL SECTIONS

Structural sections have designed pavement thicknesses that closely resemble real-world pavements with embedded strain and pressure sensors that measure pavement responses to loads for validation of mechanistic-empirical pavement design procedures.

Additive Group (N1, N2, N5, N7, S5, S6)

An experiment to study the impact of various mix additives on pavement life is the core of the structural research effort within the new group experiment. Group experiments are projects that address a national

Rachel Cousins (left) works with Matthew Sasser (right) to sieve mix for embedding the instrumentation in Section S5 of the Additive Group experiment.

need where the costs of construction, operations and research are shared in a cooperative manner. The Additive Group is sponsored by Alabama DOT, Florida DOT, Mississippi DOT, New York State DOT, Tennessee DOT, Texas DOT and the Federal Highway Administration. Recycled plastic additives, recycled tire rubber additives and aramid fiber additives will be evaluated using balanced mix design methods. The objectives are to comprehensively evaluate the field performance impact of multiple mix additives at the same time, develop a laboratory testing framework to provide a good indication of field performance and establish a framework to evaluate future mix additives with a validated pavement model.

Section S6 of the Additive Group is paved on the south side of the NCAT Test Track.

The mix for BASF's Section S13 is transferred from the truck to the paver by a shuttle buggy.

BASF (S13)

Section S13 is sponsored by BASF Corporation to evaluate their new reactive isocyanate based modifier (B2Last®). This section has the same pavement structure as the Additive Group test sections and is considered to be complementary to that experiment. The only difference between this section and the Additive Group control section is the binder used to produce the mixture contains B2Last® and a linear styrene-butadiene-styrene (SBS). The modified binder is graded as a PG 82-22.

Virginia (S12)

Virginia DOT has continued their sponsorship of cold central plant recycling (CCPR), but this time with a new spin. After the success of Section S12 undergoing 30 million equivalent single axle loads (ESALS) with no deterioration, it was decided to investigate what happens when the CCPR is re-recycled. The surface and CCPR layers were separately milled, the base re-worked to consist of track subgrade with a 6-inch aggregate base, and then the CCPR was re-recycled using a mobile CCPR plant and surfaced with a 2-inch Virginia SMA. The asphalt in the CCPR is now living its third life in an innovative experiment to further explore the circular economy of asphalt pavements.

Rejuvenated CCPR (Off-ramp)

In a first-of-its kind experiment, a rejuvenated CCPR experiment has also been constructed on the Test Track off-ramp. Produced using either a typical mobile CCPR plant or a mobile pugmill, five sections were constructed: a foamed asphalt, an engineered emulsion, two rejuvenated emulsions, and a rejuvenator. Because the rejuvenated mixtures are expected to perform somewhere between a typical CCPR and a hot-mix asphalt (HMA) base mixture, an HMA mixture was placed as the base of a sixth section for comparison. All sections were topped with a 4.75 mm NMAS thin overlay. The sections will be monitored closely and laboratory characterization of all of the mixes has commenced.

CONTINUING EXPERIMENTS

Several sections on the Test Track will continue to be evaluated with additional traffic and environmental exposure during this cycle. Detailed information for these test sections is available in NCAT Report 21-03, Phase VII (2018-2021) NCAT Test Track Findings.

Alabama DOT (N10, N11)

This study is evaluating the performance of two thinlay test sections placed in 2018 as a pavement preservation treatment for high volume roads. Section N10 used a 4.75 mm NMAS stone matrix asphalt (SMA) mix, and Section N11 used a 4.75 mm NMAS dense-graded Superpave mix. I-FIT results showed statistically similar FI results for both mixes, however, they were lower than the criterion established for Illinois DOT surface mixes. On the other hand, IDEAL-CT results were significantly higher for the SMA in N10 compared to the Superpave mix in N11. Despite these results, there has been no field cracking; therefore, monitoring of these sections will continue to assess their long-term cracking performance.

Cargill (N3)

This experiment is being continued to evaluate the effectiveness of Anova asphalt rejuvenator with high RAP mixtures within the balanced mix design framework. The experiment compares two surface mixtures placed in 2018. Section N3A was milled and inlaid with a control mixture containing 30% RAP and a PG 64-22 binder. Section N3B was inlaid with a mixture containing 45% RAP, a PG 64-22 binder and Anova asphalt rejuvenator. The BMD test results indicated that mix with Anova asphalt rejuvenator improved cracking resistance without affecting the mixture's resistance to rutting. So far, the two subsections have shown comparable field performance.

Florida DOT (E5, E6)

The objective of this experiment is to evaluate the effect of density level on pavement performance. The testing plan will also conduct BMD tests on the mixture at the same density levels achieved in the test sections. For this experiment, one asphalt mixture containing 20% RAP and a polymer modified binder was placed and compacted in four 100-foot test strips in Sections E5 and E6 in 2018. Average in-place densities were 87.8, 89.7, 92.0 and 93.5% of G_{mm}. So far, the lowest density section is the only one to exhibit cracking. An additional round of traffic is needed to better determine the effects of density on performance.

Georgia DOT (N12, N13)

This study aims to evaluate six different reflective cracking treatments including two geosynthetic interlayers, two chip seal systems, an open-graded interlayer mix and a rubber modified asphalt interlayer. After 10 million ESALs of trafficking, no reflection cracking was evident, the surface roughness of all subsections remained about the same, and all sub sections exhibited comparable surface macrotextures. The only meaningful difference in the subsections has been the RAP chip seal subsection (N13A) with a greater rut depth. Trafficking and field performance of all subsections will continue to be monitored in this research cycle.

Mississippi DOT (S2, S3)

Section S2 was constructed in 2018 to evaluate a flexible pavement with a stabilized subgrade and base foundation. The performance of the pavement through one cycle has been excellent. Total rutting was less than 0.15", no cracking was observed, and smoothness did not appreciably change. Structural health monitoring from imbedded instrumentation also showed no significant changes over time. Measured stresses in the pavement structure followed expected trends, with stresses decreasing with depth and increasing exponentially with temperature of the asphalt concrete. Linkages between performance measurements and structural characterization will provide needed data sets for M-E analysis and design of stabilized foundation sections. This section will remain in place with continued surface performance monitoring (i.e., rutting, cracking and ride quality) and structural response measurements (i.e., stress, strain measurement and FWD testing). To further investigate and validate the findings from S2, MDOT is also constructing an instrumented test section on State Route 76 near Tupelo, Mississippi.

Mississippi DOT sponsored an experiment on Section S3 to evaluate the field performance of spray-on rejuvenator products over time. The study examined their short- and long-term effectiveness in renewing asphalt surfaces and their effects on surface friction after application, as well as how these products can be evaluated in the laboratory. Section S3 was divided into two subsections: one treated with a plant-based topical rejuvenating seal and the other treated with a proprietary age-regenerating surface treatment. The rejuvenating capability of each product was assessed considering rheological parameters and surface friction measurements. After reviewing the results, Mississippi expressed their contentment to the fact that the evaluated spray-on rejuvenator products can be effective for restoring the asphalt binder properties of a treated pavement surface and will continue to sponsor S3 throughout the upcoming research cycle.

Oklahoma DOT (S1)

The main objective of this experiment is to help ODOT with implementation of mixture performance testing and criteria for BMD. Two sections were built in 2018 as mill-and-inlays using asphalt mixtures designed with a BMD approach. Section N9 was placed as a 1.5-inch layer while S1 was placed in two layers with a total thickness of 5.0 inches. ODOT sought to determine if the proposed criteria in their BMD provisional specification were sufficient, or if they needed to be adjusted to achieve good rutting and cracking field performance. In the previous cycle, both sections performed very well with minimal rutting and cracking and exhibited steady smoothness and texture results. Skid numbers declined slightly but remained well above the general safety threshold. Trafficking and monitoring of Section S1 will continue during this research cycle.

South Carolina (S9)

Section S9 was constructed in 2018 as an 8.05″ single thick-lift pavement on a prepared crushed granite aggregate base to evaluate the constructability, performance, and structural characteristics of this rapid reconstruction technique. The section has shown excellent performance similar to conventional multi-lift sections with less than 0.25″ rutting, very little cracking, and no change in smoothness. Structurally, the temperature-corrected backcalculated AC moduli and measured pavement responses were remarkably consistent over time, indicating good structural health despite the small amount of cracking observed in the section. Laboratory determination of AC dynamic modulus produced consistent data, and either data set could be used for future mechanistic modeling. Cracking tests using the bending beam and cyclic fatigue tests produced vastly different transfer functions and additional trafficking and cracking development will be required for calibration. Since only minor cracking has been observed through 10 million ESALs, further monitoring will help determine an acceptable threshold.

Texas DOT (S10, S11)

In the 2018 research cycle, TxDOT sponsored a BMD surface experiment to compare the field performance of asphalt mixes designed using a BMD approach (S10) versus the traditional volumetric approach (S11). Both sections were built as 2.5-inch mill-and-inlays over an existing asphalt pavement with approximately 15 to 20% cracked lane area to challenge the surface mixes. Both sections performed well after 10 million ESALs. The BMD mix exhibited a little over 0.3″ of rutting and the volumetric mix design had a little over 0.2″ of rutting, both well below the threshold of 0.5 inches. The BMD mix had considerably less reflection cracking than the volumetric mix design, which was consistent with the Texas Overlay test results. The two sections had similar smoothness and friction characteristics. Both sections will remain in place for additional trafficking and long-term performance evaluation.

United Soybean Board (W10)

A bio-derived polymer produced from the transesterification of glycerol from the triglycerides in epoxidized soybean oil was tested as part of the 2018 research cycle. This bio-polymer, which includes epoxidized benzyl soyate (EBS), is thought to also improve the resistance of asphalt binders to oxidative aging as the epoxide rings within the EBS react to form crosslinks and block nucleophilic sites where asphalt oxidation occurs. In this experiment, the EBS-modified surface mix is compared against a control section (E5A) containing a traditional SBS polymer for texture, rutting and cracking performance. Both sections have carried 10 million ESALs of trafficking with comparable field performance thus far. No cracking was observed for the EBS-modified mixture while low severity cracks were recorded for 0.4% of lane area with the SBS-modified mixture. These sections will be kept in place for continued trafficking, which will be important to evaluate the long-term performance of the bio-polymer modified asphalt against the conventional SBS modified asphalt.

Virginia DOT (N4)

In 2012, Virginia DOT initiated an experiment to evaluate how a cold central plant recycled (CCPR) pavement layer would perform under heavy traffic loads. The experiment also sought to understand the stress and strain distribution in the pavement, as well as identify the failure mechanism and the rate of deterioration to help plan future maintenance and rehabilitation strategies. Three test sections using CCPR performed exceptionally well through two test cycles. In 2018, VDOT decided to continue trafficking on the two that had 4″ of HMA over the CCPR layers. After the third test cycle, both of those sections were still performing very well. VDOT has decided to continue trafficking only on Section N4 so that the deterioration rate can be observed. This, along with data collection and forensic analysis at the conclusion of the test, will provide VDOT with insight on how CCPR materials fail, the rate at which they may fail, and validation data that can be used for mechanistic-empirical pavement design.

Pavement Preservation Group

NCAT launched a productive partnership with the Minnesota Department of Transportation's Minnesota Road Research Project (MnROAD) in 2015 aimed at producing findings that can be directly implemented by a larger geographic base by incorporating a cold-weather climate. NCAT is continuing this collaboration for the Additive Group experiment and continues the research partnership on the pavement preservation group study. This highly controlled experiment includes monitoring numerous preservation treatments on public roadways to quantify the condition-improving benefit curves for each treatment or treatment combination under different levels of traffic and very different climates.

EXAMINING PERFORMANCE

Trafficking begins this fall and will continue over a period of two years. Each section on the track is subjected to 10 million equivalent single axle loads of heavy truck traffic and performance is closely monitored on a weekly basis. Drivers currently operate NCAT vehicles in order to best induce representative vehicle wander, but autonomous systems are expected to be implemented in the future.

An automated pavement distress data collection vehicle is used to quantify roughness, macrotexture, rutting and cracking in the same manner used by most state highway departments for their pavement management systems. Other tests such as surface friction, falling weight deflectometer, tire-pavement noise and permeability data are also conducted. Similar performance data is conducted for off-track sections on a less frequent basis due to the open traffic on these roadways.

The final part of the three-year cycle will involve forensic analyses of damaged sections in order 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. Test sections will either be replaced or remain in place for additional evaluation during the ninth research cycle in 2024.

NCAT added two new trucks to its fleet for the track's eighth cycle.

Recent Friction Studies at the NCAT Test Track

Given that the NCAT Test Track is surfaced with a wide variety of asphalt mixtures and surface treatments that utilize a range of aggregate types and gradations, it is an ideal platform to conduct tire-pavement friction research. The closed facility's extensive range of pavement surfaces with distinct friction characteristics is perfect for conducting studies to examine how friction changes with traffic and time, how aggregate properties and pavement surface textures influence friction, the performance of special surface mixes and treatments, and to compare different friction measurement devices.

West Virginia Division of Highways (WVDOH) recently sponsored a study to evaluate the feasibility of increasing the dolomite content in surface mixtures. West Virginia has a source with an abundance of dolomites, but they are known to be highly susceptible to polishing. Two test sections, W4 and W5, were built in 2018 using 70% and 90% dolomite coarse aggregates in the surface course, respectively. Dynamic friction tester and locked-wheel skid trailer (LWST) tests were conducted to determine the friction performance of these two sections.

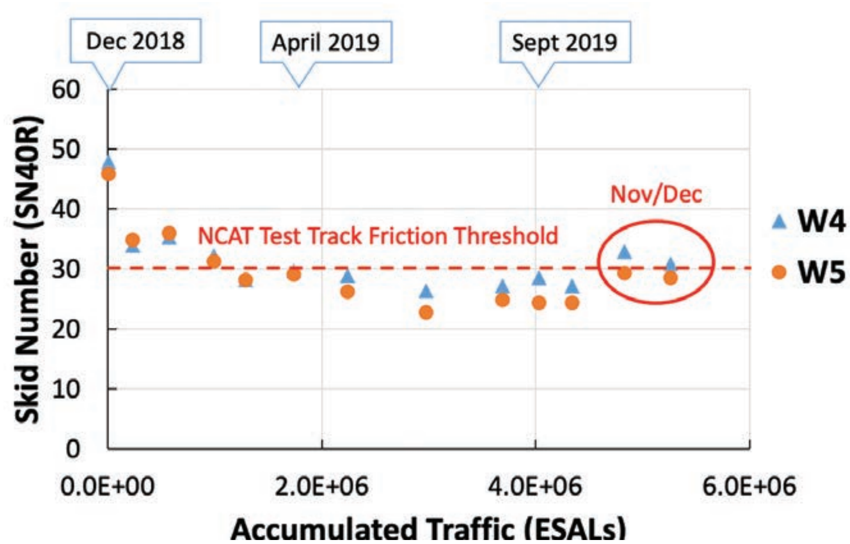
Figure 1 demonstrates that replacing sandstone coarse aggregates by 70% and 90% dolomite resulted in asphalt surface mixtures with fairly low long-term skid resistance. These results validated WVDOH's requirement that dolomite shall not exceed 50% of coarse aggregate in asphalt surface mixtures when the projected traffic volume is greater than 3 million equivalent single axle loads (ESALs).

Shotblasting the pavement surface has been used as a technique to restore the skid resistance of polished pavement. The shotblasting system consists of a shot propeller to blast the steel balls, a vacuum unit to recover the abraded material from the road surface, a magnetic separator to collect the steel shots for reuse, and a residue container, followed by a power broom to sweep away residual loose particles. This technique was used for five test sections with low skid resistance (skid number <30) at the Test Track.

According to the measurement results, the surface friction and texture properties of the test sections were substantially improved immediately after shotblasting treatment. The surface mixture and aggregate types were significant factors affecting the capability of the shotblasting treatment to restore friction and texture characteristics. After 5 million ESALs of trafficking, the shotblasting treated sections still had skid numbers above 30, indicating the effectiveness of this treatment. The shotblasting technique was not detrimental to the pavement condition in terms of roughness, rutting, or cracking.

In 2020, another study evaluated the repeatability of friction measurements using the LWST and the sideways-force coefficient routine investigation machine (SCRIM). As presented in Table 1, this study included 14 test sections with different surface texture and friction characteristics. The LWST and SCRIM tests were conducted at 30, 40, and 50 mph test speeds and different test times (or temperatures) on two consecutive days.

Figure 1. Friction Performance of NCAT Test Track Sections W4 and W5



Shotblasting system on Section W5 at the NCAT Test Track.

This study found that an acceptable precision of friction measurements was within 2.5 skid number units or 3 skid resistance units. In addition, the study concluded that the LWST skid number and SCRIM readings had a good linear correlation, particularly in the straight test sections. This study confirmed that increasing test speed or test temperature reduced the measured friction values. Regression models were developed to correct the friction measurements at any given speed or temperature to a reference speed or temperature.

Table 1. Sections from the NCAT Test Track Selected for Use in 2020 Friction Study

Section ID	Surface Type	Aggregate Type	Year Placed
E1	OGFC	Lms/Granite	2012
E5	Dense Graded	Granite/Sand (20% RAP)	2018
E8	Dense Graded	Granite/Sand (30% RAP)	2015
N1	Dense Graded	Granite/Sand (20% RAP)	2015
N4	SMA	Traprock (11% RAP)	2012
N7	DG	Granite	2015
N10	SMA	Granite	2018
W2	Chip Seal	Lightweight Aggregate	2012
W5	Dense Graded	Sandstone/Dolomite	2018
W8	HFST	Bauxite	2011
S1	Dense Graded	Granite	2018
S4	Surface Rejuvenation	Lms/Sand (15% F-RAP)	2018
S8	Dense Graded	Granite/Sand (20% RAP)	2015
S11	Dense Graded	Granite	2018

Contact Fan Gu at fan.gu@auburn.edu for more information about this research.

Paths to BMD Implementation

Across the USA, many highway agencies are beginning the journey toward a new way of designing and accepting asphalt mixtures using the balanced mix design (BMD) system. Like pioneers during the American westward migration in the 19th century, several states have already crossed into unchartered territory, while others are now looking for information on the best path to take. To help with that journey, NCAT has been working on a guide for BMD implementation as a primary deliverable for NCHRP project 10 107. The draft implementation guide is currently being vetted through a stakeholder review process. A webinar and workshops are being planned for early 2022. The draft guide includes eight tasks (briefly described as follows), along with many more details, recommendations and suggested resources.

Task 1: Motivations and Benefits

Although each agency will likely have several reasons for implementing BMD tests and related specifications, motives are typically rooted in dissatisfaction with the status quo. For example, an agency may want to improve the average service life of their asphalt overlays by "weeding out" poor-performing mixes that pass their existing specifications but just don't perform well, or they may want to better assess the impact of using recycled materials and/or innovative additives on pavement performance.

The original vision of the Superpave mix design system was to include mixture performance tests in the mix design process for moderate and heavily-trafficked pavements, but the proposed tests from the SHRP program were only used for a few special projects, primarily because they were not practical for routine use for the thousands of mix designs used each year. Most state DOTs have revised Superpave mix design and binder requirements to make incremental improvements in the quality of their asphalt mixtures over the past 20 years. However, the dependence of the Superpave mix design system on volumetric requirements to assure good durability, particularly voids in mineral aggregate (VMA), means volumetric design criteria are also dependent on an accurate aggregate bulk specific gravity, which unfortunately has such poor precision that it is not a reliable property to ensure mixture durability.

Task 2: Overall Planning

Implementation of BMD will take as much effort as the implementation of Superpave two decades ago. To accomplish this, it is essential to have highway agency and industry champions who will help overcome institutional challenges and resistance to change. Successful implementation will also require a well thought out plan and a joint agency-industry technical committee to shepherd the process and make key decisions along the way. One of the first steps is to set long-term goals and intermediate milestones. For example, some states may want to fully implement BMD tests and associated criteria for mix design and project acceptance of asphalt mixtures, but will first work toward an intermediate milestone of implementing BMD just for mix design approval. Other states may desire to only utilize BMD tests and criteria for projects on higher traffic, and/or high profile roadways. In communicating the plan to all stakeholders, it will be important to provide estimated timelines for the short-term and long-term goals, as some of the tasks in this plan are likely to take several years to complete.

Task 3: Selecting Tests

The first major decision along the path to BMD implementation is the selection of performance tests, which should begin with a basic understanding of the types of asphalt pavement distresses that are most prevalent in the state. Basically, it's critical to know what aspects of pavement performance need to be improved – whether it's reflection cracking, thermal cracking, moisture damage problems, raveling, rutting, or some other distress.

Once the BMD technical committee has that established, important factors to consider in selecting the appropriate tests include correlation to field performance, cost of the equipment, test variability and overall turn-around time from sampling to results. NAPA's online BMD Resource Guide is an excellent resource for information on the BMD tests and many other aspects of BMD implementation See the QR code on the next page to access the NAPA BMD Resource Guide.

In order to validate the selected BMD tests, states are strongly encouraged to consider field experiments similar to the Long-Term Pavement Performance SPS-9A experiment, *Verification of SHRP Asphalt Specification and Mix Design* (i.e.

Superpave). A few pooled-fund projects, such as the NCAT Test Track and NRRA experiments, may also be helpful when correlating field performance to BMD test results, but local experimental projects using mix designs developed with that state's existing criteria and a range of BMD test results will be crucial for setting appropriate specifications further down the path of implementation.

Task 4: Acquiring Needed Resources

Preparing for the purchase of BMD and ancillary equipment (e.g. ovens, saws, etc.) often needs to be done well in advance of each organization's budgeting cycle. Keep in mind that some existing labs may be constrained by space or electrical capacity, so additional lab space and or electrical circuits may also be needed (which will require even more lead-time). Consideration also needs to be given to staffing demands, which will largely depend on the new tests selected, the frequency of testing, and how many of the existing requirements will remain in-place once BMD tests are added for mix design approval and/or production acceptance.

Task 5: Establishing Baseline Data

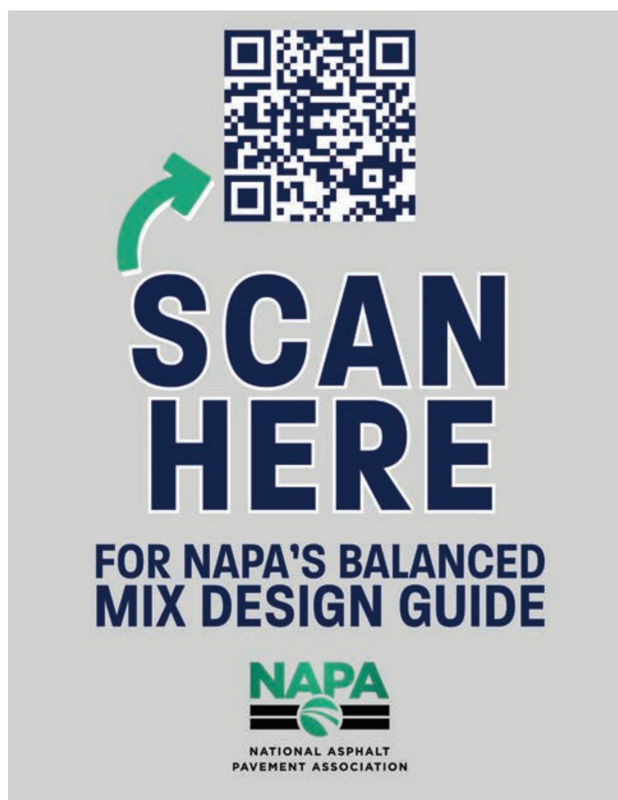
This task requires significant efforts by each state and the industry to gather information necessary for setting appropriate criteria for mix design approval and acceptance during mix production, assuming the latter is a goal set by the agency. One source of information will come from benchmarking studies, which refers to the testing of existing mix designs across the state to assess the distribution of results. Each state should conduct its own benchmarking study, which will have two parts. One part is for lab-prepared mixes, such as used in mix design. The second part involves testing plant mix samples to represent tests for acceptance. Preferably, one lab would be responsible for conducting the benchmarking testing since using more labs would introduce between-lab variability in test results.

Another critical source of information will come from shadow projects. Shadow projects are paving projects on which mixes are sampled for the normal acceptance tests, but additional samples are also pulled for BMD tests that are performed in the background. Results of the BMD tests from shadow projects are not used to accept or reject materials, adjust payment or even to motivate mix production changes. Rather, the three goals of the shadow projects are to: (1) better familiarize both agency and contractor personnel with the selected tests, (2) add to the database of test results from the benchmarking studies, and most importantly (3) gather information on typical production variability. Recommendations on the number of shadow projects, the number and frequency of BMD tests per project, and how the samples are prepared and tested are discussed in the draft implementation guide.

Task 6: Specification and Program Development

This task involves the development of the specifications and quality assurance program to be used for implementation. The information gathered from the previous tasks will be used for this effort, and decisions must be made about what aspects of the current specifications need to remain the same and what existing criteria should be relaxed or completely eliminated. Consideration should be given to how to adapt the acceptance of lots based on specification criteria with two-sided limits (e.g. lab compacted air voids) to test criteria that are one-sided (e.g. minimum cracking index and maximum rut depth). If the BMD test results are used for pay adjustments, then there must be confidence that the results are truly performance related, which goes back to the need for field validation experiments in Task 3.

Once the new specifications are vetted by stakeholders, then it's time to plan and conduct pilot projects. Pilot projects are necessary to evaluate the new QA program requirements under



NCAT's draft guide includes eight tasks to BMD implementation.

actual contractual conditions. Pilot projects will go through the typical bidding-contracting process with the new QA requirements and specifications applied, including BMD testing required as part of mixture design and acceptance. The number of pilot projects should be determined by the agency, typically starting with just a few projects in the first year, then increasing to involve additional districts/regions and contractors each year. Lessons learned from pilot projects should be used to assess and modify the specifications and QA program requirements on a yearly basis, with more frequent modifications for more acute issues.

Task 7: Adapting Training Programs and Lab Accreditations

As an agency begins rolling out pilot projects, it will need to conduct just-in-time training to cover the new testing requirements and specification changes in the QA program. Likewise, the agency also needs to establish new independent assurance requirements for labs conducting tests used for mix acceptance to ensure the technicians and equipment meet the requirements of the new procedures. The state's on-going technician training and qualification program will also need to be adapted to include the changes and a plan to recertify technicians who are already qualified but are not familiar with the new tests and requirements. Many states already have a proficiency testing program for their current quality assurance tests as a means to ensure technicians perform the tests correctly and to continuously evaluate test precision information. These programs should be expanded to include the new BMD tests.

Task 8: Initial Implementation

Prior to full implementation of the BMD requirements, it is essential that the agency communicate the changes and new requirements to both industry and DOT personnel. This technology transfer can be accomplished through webinars, face-to-face meetings and workshops, and can also be supported by implementation teams that help contractors and DOT personnel get ready for the changes, address issues and interpret specification requirements. The initial implementation should be viewed as a new beginning with an expectation that the QA program will continue to evolve toward a system that efficiently assesses mix characteristics that relate to long-term performance.

Which Cracking Test?

NCAT's Test Track Provides Answers.

Most state DOTs and contractors now agree that changes are needed in the way that we conduct and approve asphalt mix designs and measure mixture quality during pavement construction. A new era is dawning on the process for asphalt mix design and quality assurance testing based on balanced mix design (BMD), centered around simple mechanical tests that provide better indications of how a mix can resist the most common forms of distress. Most stakeholders recognize the limitations and deficiencies of the current system based on volumetric properties. In retrospect, the Superpave mix design system was supposed to include mixture performance tests for moderate and high traffic roadways; however, those performance tests were not practical for routine use.

The first mountain to climb on the path toward BMD implementation has been to decide which tests to use. Over the past several decades, numerous rutting, cracking, and moisture damage tests have been proposed by researchers. However, most of the tests have lacked field performance validation with no consensus on which tests are suitable for day-to-day usage.

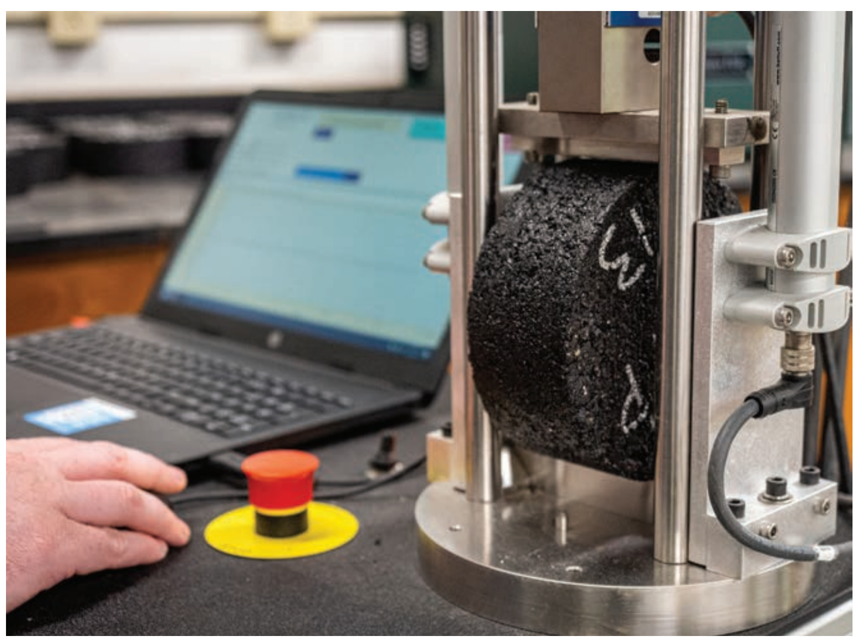
In 2015, NCAT launched a new experiment on the Test Track to provide correlations between top-down cracking and results from several of the most promising cracking tests. That study, known as the Cracking Group experiment, was funded by the FHWA and DOTs in Alabama, Florida, Illinois, Maryland, Michigan, Minnesota, Mississippi, New York, North Carolina, Oklahoma, and Wisconsin. The experiment included seven test sections built with the same pavement structure but with differing surface mixes, including mixtures that were expected to have cracking resistances ranging from poor to very good. Even with the pounding loads on the Test Track, it took over four years to develop a meaningful spread in the amount of cracking among the seven test sections.

Aging of surface layers is a critical factor in the development of top-down cracking. As part of this study, NCAT developed a "critical-aging" protocol to simulate the four to five years of in-service aging of surface layers. The term critical aging was coined to differentiate it from long-term aging. The goal of the critical aging protocol is to age mixtures in the lab just to the point where top-down cracking typically begins to appear in pavements. The critical aging protocol for Alabama conditions is aging of loose mix spread out in a pan at a depth of no more than ½" for eight hours at 135°C.

Seven laboratory cracking tests were selected for evaluation by the sponsors for the experiment. Conducting the cracking tests on all of the same mixes at the same time provided an easy way to compare other concerns such as testing time, variability, and complexity, which are important considerations for tests to be used in day-to-day practice. Based on the results of the NCAT top-down cracking experiment, the following findings and recommendations were provided.

IDEAL Cracking Test (IDEAL-CT)

CT_{Index} from the IDEAL-CT method is a very good indicator of top-down cracking resistance. It has strong correlations to the field performance of the



The Indirect Tensile Asphalt Cracking Test (IDEAL-CT) can determine the cracking potential of asphalt mixtures.

NCAT test sections and the results are statistically discernable from mix to mix. For critically-aged samples, a minimum CT_{Index} of 15.0 was found to be a good criteria for top-down cracking based on the data. However, CT_{Index} results are affected by specimen air void contents in an incorrect manner. Specimens with lower air voids have lower CT_{Index} results, which is counter to the field cracking performance as evidenced by the test sections on the track. Until this issue is corrected, the test should only be conducted on specimens compacted to 7.0±0.5%. The IDEAL-CT method is the most practical of the evaluated cracking tests and is well suited for everyday use in BMD and quality assurance testing.

Illinois Flexibility Index Test (I-FIT)

The flexibility index from the I-FIT procedure correlated well with top-down cracking observed for the test sections. However, due to higher variability of *FI* for several mixtures, the critically aged plant mix results were not statistically distinguishable among some good and moderately performing mixtures or between good and poor performing mixtures. A disadvantage of the I-FIT is the time and cost of preparing specimens, which includes cutting and notching of the semi-circular test specimens. Also, like CT_{Index}, *FI* results are affected by specimen air void contents in an incorrect manner.

Texas Overlay Test (OT-TX)

The cracking progression rate (CPR, also referred to as the β parameter) from the OT-TX test is a very good indicator of a mixture's resistance to top-down cracking. It is a much more discerning cracking indicator than the traditional OT criteria of "cycles to failure". For OT-TX tests on critically-aged mixtures, a CPR value of 1.75 separated mixtures with moderate top-down cracking resistance from mixtures with very good performance. However, the OT-TX test is not practical for day-to-day use in BMD and quality assurance testing due to the time required to prepare specimens and the cost of the equipment.

NCAT Modified Overlay Test (OT-NCAT)

The NCAT-modified version of the overlay test is also a very good indicator of resistance to top-down cracking. A CPR value of 0.37 is recommended as a preliminary criterion for critically-aged mixtures based on the plant mix results of this experiment. The NCAT-OT has a lower coefficient of variation than the OT-TX procedure and the testing time is faster. However, like the OT-TX, the test lacks practicality due to the time of preparing specimens and high equipment cost.

Louisiana Semi-circular Bend Test (SCB-LA)

The Louisiana SCB test did not provide a suitable correlation with top-down cracking performance of the mixtures in this experiment. Two of the mixtures that performed very well on the track had results very similar to those of mixtures with moderate cracking. Other disadvantages of the SCB-LA are the time and cost of preparing notched semi-circular specimens, and that standard methods of variability analysis cannot be applied to the results.

Asphalt Mixture Performance Tester (AMPT) Cyclic Fatigue Test

The AMPT cyclic fatigue test index parameter, S_{app}, correlated well with the observed top-down cracking for the test sections for this experiment. The results also support North Carolina State University's recommended minimum S_{app} criterion of 30 for short-term aged mixture samples for *Very Heavy* traffic pavement applications. However, the S_{app} result for the best performing test section in the experiment was lower than expected. This may indicate that the cyclic fatigue test or its criteria need to be adjusted for asphalt-rubber mixtures. Disadvantages of this test are the time and cost to prepare specimens, cost of the equipment, and complexity of data analysis. For these reasons, it is not well suited for routine use in BMD or quality assurance testing.

Energy Ratio (ER)

Energy ratio results did not match field performance for top-down cracking. This test also lacks practicality for routine use due to its complexity and time to complete the three parts of the test, so it is not recommended for implementation.

Selecting tests for BMD is the first major step toward advancing asphalt mix design and quality assurance testing. Once implemented, BMD will result in improved pavement performance and open the door to innovations that cannot be adequately evaluated with Superpave binder and mix specifications.

Contact Randy West at randy.west@auburn.edu for more information about this research.

Optimizing Recycled Materials Contents by Using Recycling Agents

Using reclaimed asphalt pavements (RAP) and recycled asphalt shingles (RAS) in asphalt mixtures can provide materials cost savings, conserve natural resources, and reduce energy consumption and associated greenhouse gas emissions. Although increasing the amount of these materials used in an asphalt mixture typically increases rutting resistance, it can also increase its susceptibility to cracking and may cause durability issues if the mix design does not adequately account for the aged binder in the recycled materials.

NCAT recently completed a study for the Wisconsin Highway Research Program with the following objectives: (a) evaluate how the quantity and quality of recycled materials affect the performance of binder blends; (b) validate binder results with mixture testing, and (c) draft a procedure to evaluate the quality of asphalt blends with high recycled contents and guide the use of recycling agents (RAs) to produce recycled asphalt mixtures with optimized performance.

The Wisconsin Department of Transportation (WisDOT) currently allows up to 40% asphalt binder replacement (ABR) for lower pavement layers and 25% in upper layers. ABR is defined as the percentage of the recycled binder in the total binder (virgin + RAP &/or RAS binder).

The first part of the study evaluated the rheological and chemical properties of several asphalt binder blends with a range of recycled materials contents and additives [i.e., polymer, and petroleum- and bio-based RAs]. Testing included Superpave performance grading (PG), linear amplitude sweep (LAS), gel permeation chromatography (GPC), and other tests.

Binder results were validated through performance testing of asphalt mixtures. Mixtures were tested for rutting resistance with the Hamburg wheel tracking test (HWTT) after short-term oven aging (STOA) for four hours at 135°C. The indirect tensile asphalt cracking test (IDEAL-CT) was used to evaluate intermediate-temperature cracking resistance and the disc-shaped compact tension test (DCT) was used to evaluate low-temperature cracking resistance after being subjected to STOA plus long-term oven aging (LTOA) of six hours at 135°C. In addition, the dynamic modulus (|E*|) test was conducted at both STOA and LTOA conditions to assess the stiffness characteristics and aging resistance of the mixes.

Optimum dosages for the RAs were determined using blending charts based on dynamic shear rheometer (DSR) and bending beam rheometer (BBR) test results. In this analysis, the critical high-temperature and low-temperature of a recycled binder blend is plotted against the tested RA dosage. For bio-based RAs, an initial dosage of 5% by weight of total binder (i.e., virgin plus recycled binders) was used, while an initial dosage of 20% by weight of total binder was utilized for a petroleum-based (i.e., asphalt flux) RA. Several approaches for determining the optimum dosage determination of each RA were evaluated. The approaches are illustrated here:

- Approach 1a: Target a "20% RAP-BR" high-temperature grade of DOT control blend
- Approach 1b: Target a "20% RAP-BR" low-temperature grade of DOT control blend (Figure 1)
- Approach 2: Target a "PG xx-28" grade (i.e., match the low-temperature grade for Wisconsin climate) (Figure 2).

Approach 1a resulted in the highest RA dosage among all of the evaluated approaches. Although this approach was recommended in NCHRP Project 9-58, the researchers warned of a potential increase in moisture susceptibility of asphalt mixtures when this approach is used. Approach 1b resulted in the lowest RA dosage among the evaluated approaches. NCHRP Project 09-58 reported that this approach was insufficient to yield acceptable cracking resistance of the resultant mixture. Approach 2 resulted in an RA dosage between Approaches 1a and 1b. Therefore, the research team used Approach 2 to select the optimum dosage.

BINDER BLENDING ANALYSIS

The addition of recycled asphalt materials to virgin binders significantly increased the stiffness of the resultant blends, which would improve rutting resistance but decrease fatigue resistance,

Figure 1. Example of Approach 1b: Optimum RA Dosage Determination by Targeting the Low Temperature of the "20%RAP-BR" Grade

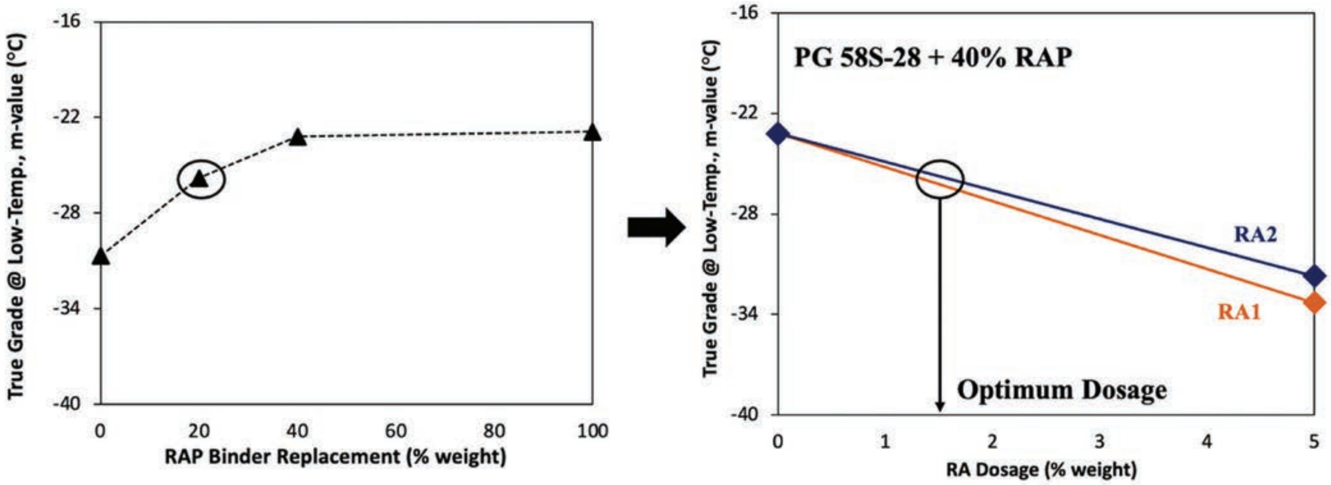
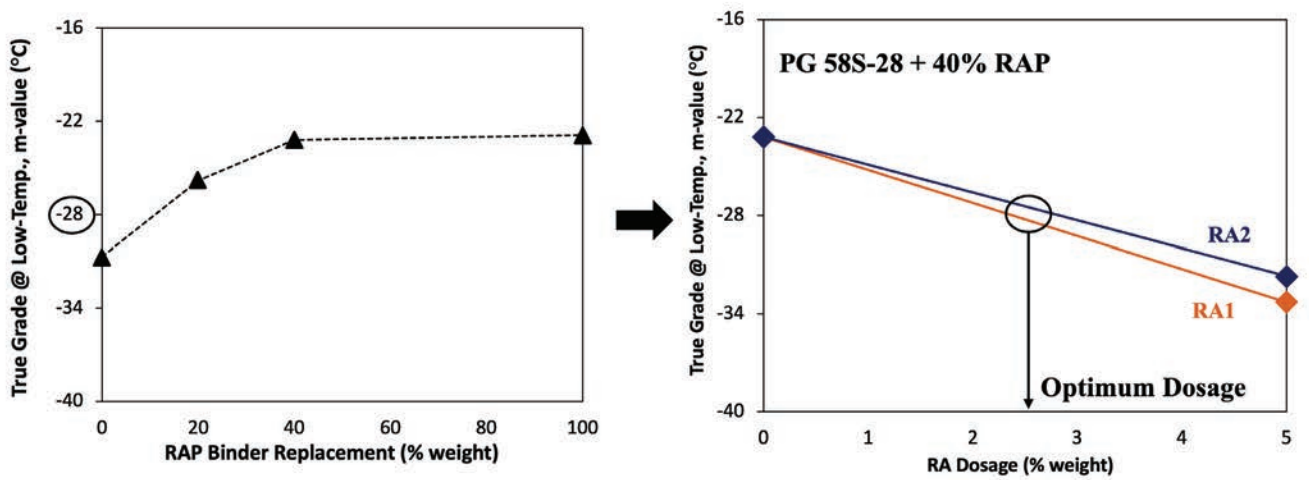


Figure 2. Example of Approach 2: Optimum RA Dosage Determination by Targeting the Low Temperature of the "PG xx-28" Grade



thermal cracking resistance, and their stress relaxation property. These effects became more pronounced as the recycled content increased. Adding bio-based RAs counterbalanced these negative effects, where the effectiveness of each RA depended on its chemical composition and its interaction with the type of recycled binder (i.e., RAP or RAS) present in the blend.

Petroleum-based RAs (i.e., asphalt flux) behaved as a softener, restoring the properties of the recycled binders only by physical process. GPC indicated that the chemical composition of this type of RA was similar to an asphaltic material. As a result, the petroleum-based RA was not effective in decreasing the cracking susceptibility of asphalt blends containing RAS. Therefore, it is not recommended for use in mixtures containing RAS.

ΔTc parameter results indicated that binder blends with up to 40% RAP ABR could still meet the preliminary threshold of -5°C after RTFO plus 40 hours of PAV aging, but 15 to 25% RAS ABR increased the cracking susceptibility of the binder blends. LAS tests indicated that blends with 25% RAS ABR substantially reduced the number of cycles to failure per unit increase in strain.

Determining the properties of the binder blends at critical pavement temperatures using standard testing equipment (i.e., DSR and BBR) was found to reliably capture material incompatibilities and potential inefficiencies of RAs. Furthermore, this approach could guide the use of appropriate proportions in a binder blend (i.e., virgin binder, recycled asphalt materials, and RA). Since the type (i.e., chemistry) of the RAs influences the aging susceptibility and their interaction with the virgin binder and recycled materials, it is necessary to understand how the binder components affect the mixture's performance properties.

MIXTURE PERFORMANCE TEST FINDINGS

Mixtures with two different aggregates (i.e., gravel and carbonate) were designed to attain ABRs of 20% RAP, 40% RAP, 25% RAS only, and 30% RAP plus 5% RAS combination. The 20% RAP ABR mixes were treated as the control mixes for performance comparison. The higher ABR mixes were rejuvenated with two different bio-based recycling agents at dosages selected using Approach 2. The RA dosages ranged from 2.1% to 5.0% by weight of the total asphalt content. The higher ABR contents were selected based on the current limits specified by WisDOT.

HWTT results showed that all of the rejuvenated mixes at higher ABRs had better rutting and moisture resistance than the control mixtures. Although, all of the rejuvenated mixes had lower IDEAL-CT CT_{Index} values than the control mixes, indicating reduced intermediate-temperature cracking resistance, only three mixes failed the preliminary minimum CT_{Index} criterion of 40 from a previous WHRP study. Two of those mixtures barely failed this criterion.

All of the rejuvenated mixes at high ABR except one had higher DCT fracture energy values than the control mixes, indicating potentially improved thermal cracking resistance. In addition, all of the mixes exceeded the minimum fracture energy criterion of 300 J/m^2 that has also been recommended for Wisconsin mixes.

|E*| showed inconsistent results for the rejuvenated mixes after STOA and LTOA when compared to the control mixes. Some of the rejuvenated mixes had higher stiffnesses while others had lower stiffness. The same inconsistency was observed for the Glover-Rowe parameter for mixtures ($G\text{-}R_m$). $G\text{-}R_m$ aging ratios showed that the rejuvenated mixes had similar aging susceptibilities as the control mixes without RAs, except for one rejuvenated mix.

Asphalt mixtures with innovative materials and high recycled contents can be better optimized with a balanced mix design approach. This will enable mix designers to determine the most cost-effective combination of materials to meet all of the mix performance test requirements. In this study, HWTT and DCT results exceeded the preliminary thresholds for Wisconsin mixtures, while some of the recycled mixtures with RAs barely failed the IDEAL-CT criteria. Therefore, slight adjustments to the dosage of RAs and/or the total binder content would be expected to provide high recycled content mixtures with balanced rutting and cracking performance.

RECOMMENDATIONS FOR IMPLEMENTATION

A step-by-step guide was developed to evaluate the quality of asphalt blends with high recycled contents and RAs to produce recycled asphalt mixtures with balanced rutting and cracking resistance. The design steps are briefly summarized as follows:

1. Extract and recover the RAP and/or RAS binder.
2. Determine the high-temperature and low-temperature performance grades of the component materials (i.e., virgin binder, RAP binder, and RAS binder) to be used for blending.
3. Blend the virgin binder with the recovered RAP and/or RAS binder(s) at the desired ABR(s) content.
4. Age the binder blend using the aging protocol of RTFO plus 40 hours in the PAV.
5. Perform the BBR test on the aged blend from step 4.
6. Determine the optimum RA dosage to achieve the low-temperature grade based on climatic requirements. For bio-based RAs, an initial dosage of 5% by weight of total binder (i.e., virgin plus recycled binders) is recommended, while an initial dosage of 20% by weight of total binder is suggested for a petroleum-based (i.e., asphalt flux) RA.
7. Conduct mixture performance tests to assess compliance with BMD performance criteria. If the IDEAL-CT criterion is not satisfied, increase the RA dosage and verify IDEAL-CT and HWTT at the higher RA dosage.

The study also recommended adding a new section for Recycling Agents to the specifications with the following suggested wording: "Recycling agents can be used to help meet the performance test requirements of mixes containing high recycled contents. Petroleum-based (i.e., asphalt flux) recycling agents should not be allowed in mixtures containing RAS as binder replacement."

Contact Raquel Moraes at moraes@auburn.edu for more information about this research.

Graduate Students Awarded AAPT Scholarships

NCAT graduate students (from left to right) Tiana Lynn, Megan Foshee and Faustina Keuliyan have been awarded AAPT scholarships.

Three civil engineering graduate students conducting research at the NCAT Test Track have received competitive scholarships and recognition from the Association of Asphalt Paving Technologists. Tiana Lynn was awarded the Ward K. Parr Scholarship with Megan Foshee selected as runner-up, and Faustina Keuliyan won the Rebecca S. McDaniel Memorial Scholarship. These annual awards, selected from an international pool of candidates, are aimed to support students pursuing careers in asphalt pavement technology.

Tiana Lynn was interested in pavements and materials at an early age and worked summers throughout high school at her parent's construction materials testing firm focusing on quality control and specimen preparation. "I grew up in this industry and I have loved it," said Lynn. "This scholarship symbolizes joining the family that is the asphalt technology industry, joining my parents as professionals in this field, and joining the legacy of those who've received this prestigious scholarship – one of which was my mother. It's a true honor."

Lynn is a second-year graduate student advised by Benjamin Bowers, assistant professor in Auburn's Department of Civil and Environmental Engineering. "I'm incredibly proud of Tiana and Faustina," said Bowers. "They've excelled in the classroom, in the lab and amongst their peers. In many ways, it was no surprise to me that they won these awards."

Faustina Keuliyan is studying modifiers that can prevent or reduce asphalt aging under the direction of Nam Tran, assistant director and research professor at the National Center for Asphalt Technology. "It's an extremely rewarding challenge to continue learning and have the potential to help bring growth and improvements into the asphalt industry through my research," said Keuliyan. "It is especially meaningful that my scholarship honors Rebecca McDaniel, an inspiring woman who made game-changing contributions to the industry. It has definitely motivated me to keep working hard towards my goals and share my own experiences with the rest of the asphalt pavement community."

NCAT Adapts For Successful Hybrid Conference

Conference attendees visit NCAT's pavement preservation research on Lee County Road 159.

NCAT hosted its first-ever hybrid Test Track Conference June 22-24, 2021, at the Hotel at Auburn University and Dixon Conference Center in Auburn, Alabama. A combination of 367 virtual and in-person guests attended to learn about cost-effective and performance-improving innovations in the design, construction, preservation and maintenance of asphalt pavements.

Held at the conclusion of each three-year phase of research, the conference is an opportunity for researchers at NCAT – partnering with the Minnesota Department of Transportation's MnROAD facility – to present the latest research findings from accelerated pavement testing. The seventh research cycle began in 2018 and was primarily focused on pavement preservation, balanced mix design, cracking tests and rejuvenator experiments.

Larry Rilett, director of the Auburn University Transportation Research Institute (AUTRI), was this year's opening speaker. The newly established institute is hosted and supported within the Samuel Ginn College of Engineering and provides a unified presence and strategic direction for promoting Auburn's world-renowned transportation research.

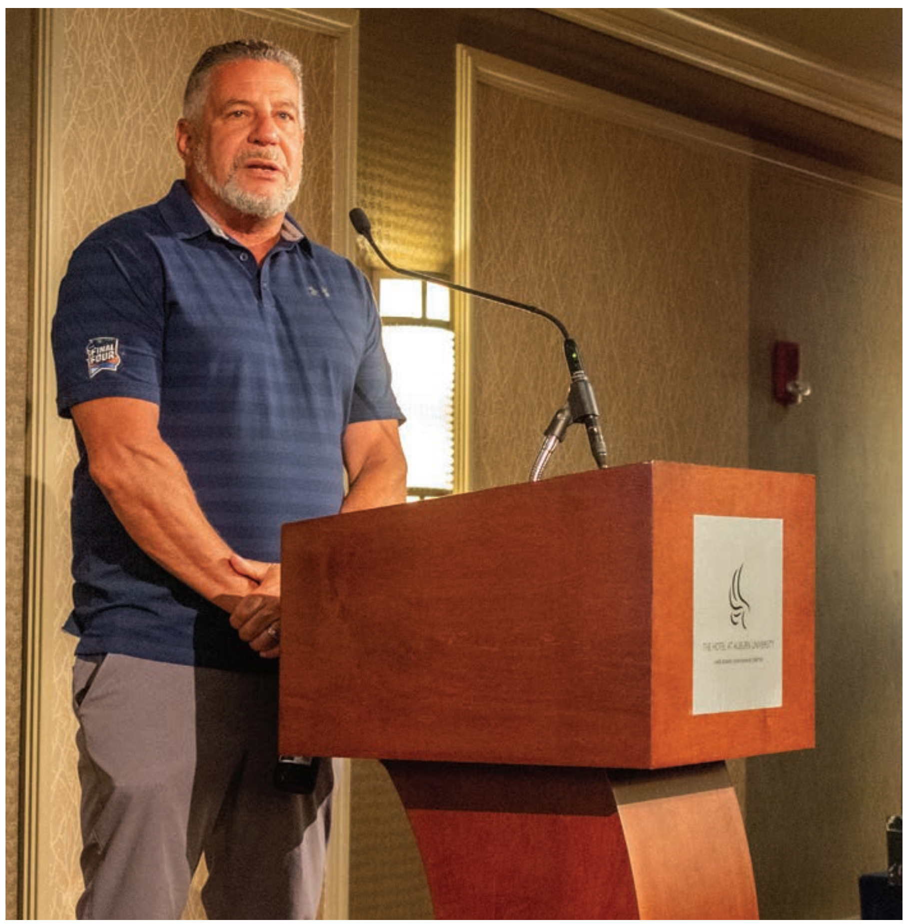
Tuesday and Wednesday's presentations detailed findings from researchers at NCAT and MnROAD. Attendees visited the Test Track on Tuesday to view numerous test sections, high friction surfaces, track instrumentation, profiling equipment and test methods.

Former NCAT students Alfredo Castro (left) and Clint Van Winkle (right) meet up in the exhibit hall.

Pavement preservation was Wednesday's central focus, where a walking tour of Lee Road 159 provided an opportunity to evaluate the life extending and condition improving benefits of various techniques. Virtual tours from both locations were shown for online attendees and are now available on the NCAT YouTube channel. Other in-person events included meals, an evening reception, and a Q&A format dinner with Auburn basketball coach Bruce Pearl.

David Timm, Brasfield & Gorrie Professor of Civil Engineering, explains how strain gauges are used to monitor structural sections on the track.

Representatives from sponsoring agencies offered testimonials about how implementing test track research has helped their states build safer, longer lasting asphalt pavements, while private industry sponsors touted the benefits of independent verification of product claims and efficacy from a trusted industry source. "NCAT's success is our success," said Everett Crews, director of R&D pavement technologies at Ingevity. "This 16-year partnership has improved our ability to build field experiments that accurately reflect and confirm performance of both new and traditional asphalt paving technologies. When NCAT proves that something works, we can take that around the world."



Auburn basketball coach Bruce Pearl delivers candid answers to questions from the audience.

The conference concluded on Thursday with remarks from NCAT Assistant Director Buzz Powell regarding upcoming reconstruction of the track for the next phase of testing, while NCAT Director Randy West and MnROAD Operations Engineer Ben Worel discussed future research opportunities.

NCAT would like to thank the Test Track sponsors, conference attendees, exhibitors and reception sponsors, whose dedication was essential to the success of this event. A complete report detailing the findings of NCAT's seventh research cycle is available online at http://ncat.us/testtrack/reports.

Asphalt Forum

Florida has a problem with a pavement distress known as "road worms" or "blisters." It has been documented since the early 1970's. There has been much speculation, but most believe it is caused by trapped moisture that vaporizes in hot weather and increases in volume between pavement layers, causing a blister to form on the surface. Debate exists of whether the moisture comes from the surface and penetrates into the pavement or comes from the lower granular layers and rises. A recent FDOT funded research project with ARA examined this issue and involved substantial field investigation of five roadways from various regions of Florida. Each roadway had road worm and control sections. The consensus for these five projects is that the moisture was coming from the top, and pavements with low in-place density and low interlayer bond strength had a propensity for exhibiting road worms.

-Greg Sholar, Florida DOT

At what temperature should the Hamburg wheel test be conducted?

-John Garrity, Minnesota DOT

How do other states determine when or if they can deviate from the AASHTO R 35 specified gyration level? In Montana, traffic over 3 million ESALs isn't all that common, so we decided several years ago to just use 75 gyration mixes. Obviously, we have numerous roads with less than 0.3 million ESALs, but we chose 75 for consistency. Now that states are using 30, 50, 60, etc. gyrations, I wonder: how do you get there? As an example, we have an out-of-state limestone quarry that wants to get into our market, but they claim they can't develop a 75 gyration design and want us to allow a 60 gyration design. This area of our state doesn't have good aggregate so a nearby limestone source would significantly reduce costs. This mix has performed in the supplier's local area. How do we adjust our contract language to take advantage? Do other states adjust gyration level by aggregate type? Is it strictly by traffic or have you conducted other research that resulted in a systemic decision to use a non-standard gyration level? Is it simply a project by project decision?

-Oak Metcalfe, Montana DOT

Example of road worms, photo courtesy of Greg Sholar.

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

> What experiences have other states had with balanced mix design? What were the challenges of BMD and performance testing, and how have you dealt with them? If using a bonus/penalty system for pay with volumetrics, how did you use the same system for performance testing?
>
> -Zane Hartzog, Alabama DOT

MICHAEL STANFORD, COLORADO DOT
CDOT is currently working with the Colorado Asphalt Pavement Association to develop a balanced mix design specification utilizing HWT and Ideal CT as our preferred performance tests.

GREG SHOLAR, FLORIDA DOT
Florida has held off implementing BMD for the main reason that no proven cracking test exists yet. In addition, during production, normal variations in mixture gradation and AC values can have overly significant effects on BMD test values. These two issues need to be worked out.

BRIAN HILL, ILLINOIS DOT
IDOT currently specifies the Illinois Flexibility Index Test (I-FIT) for cracking and the Hamburg wheel tracking test for rutting. The minimum criteria for each test are required to be met in both mix design and production phases. Detailed information on the implementation effort is shown in the IDOT case study report by Hajj, Aschenbrener, and Nener-Plante shown on NCAT's BMD resources webpage (aub.ie/bmd). IDOT does not use an incentive/disincentive program with performance tests.

NATHAN AWWAD, INDIANA DOT
We are still experimenting with BMD. We've just completed an interlaboratory study between DOT labs and producer labs. It is difficult to obtain similar results even with split samples. It seems that the hindrance of BMD and performance tests is the difficulty in producing specimens and interpreting the data. At this time, it appears performance testing would be more labor intensive than standard volumetric testing.

OAK METCALFE, MONTANA DOT
Montana has had a Hamburg rut specification for many years, both in design and production, but it has been a "go/no go" specification in the field. This causes problems because there are limited devices in our state, the test takes a full day to run, and we're so spread out geographically. It's the contractor's risk to proceed or wait for the results. We specify that we will turn results around ASAP but give ourselves seven days, so that's not the best situation. Also, up until recently, we were somewhat draconian with the specification, paying full price for mix with less than 13mm and requiring R&R as soon as the rut was deeper than 13mm. The R&R specification compounds the delay in results and has caused some problems, especially when a contractor chooses to proceed, the job is short, or paving is completed before we have a result. We have now instituted a sliding scale so mix can be left in place with a penalty, but there are still some kinks to work out. As far as the bonus/penalty for volumetrics, our construction managers have the leeway to take a sample for HWTT at any time, so if a lot has a failing HWTT but is still left in place, any bonus is rescinded. This is, of course, only one half of a true BMD system. We're working on incorporating IDEAL-CT, which we hope will be smoother given the relative ease and speed of running the test.

KEVIN SUITOR, OKLAHOMA DOT
OK DOT is placing BMD projects across the state. We are working to verify specification limits and refine procedures for short-term oven aging and time limits for test completion. We have not implemented pay factors at this time.

> What type of mix design programs are being used by contractors in your state? How does your state track or record binder source changes on a job mix formula (JMF)? Do you require a revision to the JMF or notification from the contractor when a source changes?
>
> -Tony Collins, North Carolina DOT

ZANE HARTZOG, ALABAMA DOT
Mixes are designed by various ALDOT procedures indexed here: https://www.dot.state.al.us/publications/Materials/TestingManual/ProcedureTopics.html. ALDOT does not record binder source changes on JMFs. From ALDOT Standard Specifications for Highway Construction Section 410.02 (d) 2. paragraph 2 :"...A change in liquid asphalt binder source and anti-stripping agent will be allowed without a new job mix formula provided the design criteria is met by a one-point check of the mixture. The one-point check shall include the air void content, VMA, stability, flow, and TSR (tensile strength ratio) and may be determined during the production of the mix..."

MICHAEL STANFORD, COLORADO DOT
CDOT requires the contractors to submit their mix design. Our regional / district materials engineers then set the volumetric target, and approve the JMF. A new JMF is required when any material source changes (aggregate, binder, lime, etc.).

GREG SHOLAR, FLORIDA DOT
If the first question is referring to computer programs, I do not know what specific programs contractors are using. In the past, many used FDOT's Excel mix design workbook. However, since FDOT went to a new construction and mix design database system called MAC five years ago, this system also is comprehensive and could be used as a sole source program by some contractors. For binder source changes, FDOT does not require a revision to the design. Any binder source used must be on FDOT's Approved Products List and must meet the binder grade required by the contract. This information is verified on asphalt binder delivery tickets obtained at the asphalt plant by FDOT inspectors.

BRIAN HILL, ILLINOIS DOT
IDOT staff created an Excel-based program that includes a section on HMA mix design. This program is updated as needed to address specification changes. The asphalt binder source is listed on the mix design cover sheet and the HMA daily plant reports used for reporting stockpile percentages, air voids, VMA, etc. Any source changes would be shown in the HMA daily plant reports. The contractor is not required to revise the job mix formula assuming that the same asphalt binder performance grade is used.

NATHAN AWWAD, INDIANA DOT
We rely on AASHTO R 35. In the past, we had a standard spreadsheet that was required for submittal. We recently upgraded this to an online cloud-based program called DMF Entry that mimics the old sheet. It's much more efficient, automated and much easier to data mine. Per our specification, "A PG binder grade or source change will not require a new mix design. If the upper temperature classification of the PG binder is lower than the original PG grade, a new TSR value is required." Bottom line, we are approving the aggregate design.

JOHN GARRITY, MINNESOTA DOT
Minnesota does not track binder sources other than the bill of lading. Binder source changes are not tracked on the JMF and we do not require a revision to the JMF.

OAK METCALFE, MONTANA DOT
As far as tracking mix designs, Montana uses the AASHTOWare project suite of programs for materials. It has a function to store mixes. Once a mix is approved, the data is stored in the system and assigned a number. When there are changes, the contractor must submit a form indicating what has changed. The department reserves the right to re-verify a mix or not, but documents the "new" mix with a new number to keep the JMFs separate in the system. This only works for "start up" as we allow changes during production as long as performance parameters are met (volumetrics, density, Hamburg, etc.) that are not tracked. We require what we refer to as "Target Set" before 2000 tons. The contractor must submit their "targets" for VMA, VFA, VTM, and D/A, within the specified range. Once those are submitted, the contractor is allowed to make adjustments without a new JMF. If the contractor requests new targets, a new JMF must be submitted and verified.

CHARLIE PAN, NEVADA DOT
Contractors propose their JMF based on the mix design performed/approved by the department. Source changes will require a new mix design.

KEVIN SUITOR, OKLAHOMA DOT
OK DOT requires a formal request from the contractor and a new design number is generated. Along with the request, the contractor submits results from T-283 using the new source and a new set of Hamburg tests for OK DOT testing.

NEAL FANNIN, PENNSYLVANIA DOT
Producers generally use Excel programs developed by our district materials units on an ad hoc basis for mix design. Design information is entered into our centralized construction and materials management system for review and approval. If there is a change in binder source, a boil test is required, followed as soon as possible by AASHTO T 283 for moisture susceptibility.

CLIFF SELKINGHAUS, SOUTH CAROLINA DOT
SCDOT wrote a mix design program in Excel for contractors to use and submit paperwork electronically. This is updated every several years as we change gradations and likely increase performance testing for BMD. Contractors may elect to change sources of neat binders (64-22) without having to re-verify mix designs; however, if a PMA (76-22) is different, then we require re-verification of volumetric properties and performance tests at optimum binder content if applicable.

> What is the minimum and maximum lift thickness allowed in the specifications in terms of nominal maximum aggregate size (NMAS)? Virginia currently has a minimum two-and-a-half times and a maximum four times of NMAS. Are you satisfied with outcomes if you implement five or even six times?
>
> -Sungho Kim, Virginia DOT

ZANE HARTZOG, ALABAMA DOT
ALDOT does not specify maximum lift thickness in terms of NMAS. Maximum lift thickness is specified in the ALDOT Standard Specifications for Highway Construction section 410.03 (f) 1. paragraph 6: "Unless otherwise provided in the following sections of these specifications, or shown on the plans, the average rate placed and compacted in one layer shall not exceed 350 pounds per square yard {200 kg/m2} for base or binder layers, and 225 pounds per square yard {120kg/m2} for surface layers. Where the amount to be placed exceeds these limits, it shall be placed and compacted in two or more approximately equal layers or as shown on the plans."

MICHAEL STANFORD, COLORADO DOT
As a general rule of thumb CDOT also has a minimum of two-and-a-half times and a maximum four times of NMAS requirement.

GREG SHOLAR, FLORIDA DOT
Type SP-9.5: 1.0 to 1.5 inches
Type SP-12.5: 1.5 to 3.0 inches
Type SP-19.0: 2.0 to 4.0 inches
We are satisfied with these values, but it should be pointed out that we have increased the maximum thickness slightly over the years.

BRIAN HILL, ILLINOIS DOT
IDOT uses a minimum compacted lift thickness of three times the NMAS. In general, IDOT uses a maximum compacted lift thickness of six times the NMAS unless a 4.75mm NMAS mixture is used. A 4.75mm NMAS mixture has a maximum compacted lift thickness of 6.5 times the NMAS. IDOT is satisfied with the density of mixtures placed at the maximum compacted lift thicknesses.

NATHAN AWWAD, INDIANA DOT
In the past, we required two to four times the NMAS. Our pavement designs target three times. We feel this is too conservative, and have updated to at least allow up to five times. We have tried to encourage internally that 2" of 9.5mm is much better than 2" of 12.5mm. We have allowed intermediate and base up to six times NMAS in special situations with no ill effects.

JOHN GARRITY, MINNESOTA DOT
Minnesota has recommendations regarding aggregate size and minimum lift thickness but no specification requirement.

CHARLIE PAN, NEVADA DOT
Maximum 3" lift thickness for up to 3/4" NMAS.

NEAL FANNIN, PENNSYLVANIA DOT
9.5 mm, 1 to 1.5 inches
12.5 mm, 2 to 3 inches
19 mm, 2.5 to 4.5 inches
25 mm, 3 to 6 inches
37.5 mm, 4.5 to 8 inches

CLIFF SELKINGHAUS, SOUTH CAROLINA DOT
We commonly use three to four times NMAS. We are experimenting with some rapid construction rebuild sections in select areas to reduce chances of delamination between lifts and to help with limiting length of road closures. SCDOT sponsored Section S-9 on the NCAT Test Track, which uses a ½ NMAS in a single lift up to 8". We are learning that this technique should only be used when the mix is placed in a milled section where there is confinement and works best when placed in cold winter months to reduce mat temperature more rapidly. Paving thick lifts in warm to hot weather has caused less than desirable smoothness values, which often require milling or diamond grinding.

Specification Corner

ALABAMA DOT
Our first 424 T Superpave thin lift job has been constructed. It is a #4 NMAS mix at 70 lb/sy. ALDOT area personnel are happy with the results. We have approved OGFC mixes with Evotherm 3G instead of fiber to mitigate drain down. These mixes passed our drain down criteria of 0.30% at 325°F and 350°F by AASHTO T305. Future specification changes may include lowering our minimum prime coat rates. Trial projects that have been discussed include cold central plant recycling, balanced mix design, open graded crack-relief interlayer, and Superpave thick lift.

COLORADO DOT
CDOT has developed a pilot project specification, increasing the longitudinal joint density from 92% to 94% of the theoretical maximum specific gravity with a tolerance of +/- 4%. CDOT also continues working with the Colorado APA to develop a balanced mix design specification utilizing HWT and IDEAL-CT as our preferred performance tests.

FLORIDA DOT
We will be lowering our maximum allowed temperature for mixtures containing polymer modification from 370°F to 355°F. The change is based on feedback from polymer/binder producers indicating that higher temperatures (>355°F) are actually detrimental to the quality of the binder. 355°F would be an absolute maximum temperature, and target temperatures would be 20-30°F lower. Any truck load with a measured temperature >355°F would have to be wasted.

ILLINOIS DOT
We do not have any specification changes at this time.

INDIANA DOT
We have fully implemented Superpave 5. Target 5% air voids at 50 gyrations. We have seen an increase in density of about 1.5% across the board for what amounts to a zero cost specification change.

MINNESOTA DOT
We have no changes to standard specifications but are piloting a few Superpave 5 projects.

MONTANA DOT
We do not have any specification changes at this time.

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