Airport Asphalt Pavement Technology Program

Balanced Mix Design: Rutting Performance Tests

Technical Memo 2: Recommendations of Air Void Level for Flexible Airfield Pavements Mechanical Tests

Appendix C

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Airport Asphalt Pavement Technology Program

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The Airport Asphalt Pavement Technology Program (AAPTP) is a cooperative agreement effort between the **National Asphalt Pavement Association** (NAPA) and the **Federal Aviation Administration** (FAA) to advance asphalt pavements and pavement materials. The AAPTP advances solutions for asphalt pavement design, construction, and materials deemed important to airfield reliability, efficiency, and safety. The program leverages NAPA's unique technology implementation capabilities with assistance from the FAA and industry to advance deployment and adoption of innovative asphalt material technologies.

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Credit: NAPA

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List of Acronyms and Abbreviations

AC	Advisory circular
APA	Asphalt Pavement Analyzer
AV	Air voids
BMD	Balanced Mix Design
COV	Coefficient of variation
EWR	Newark Liberty International Airport
FAA	Federal Aviation Administration
HT-IDT	High temperature indirect tensile
HWTT	Hamburg wheel-tracking test
IRT	Ideal rutting test
LMLC	Laboratory-mixed laboratory-compacted
PMLC	Plant-mixed laboratory-compacted
RPMLC	Reheated plant-mixed laboratory-compacted
QC	Quality control
RTS	Reno Stead Airport
TTI	Texas A&M Transportation Institute
TEB	Teterboro Airport

Executive Summary

This study aimed to establish representative rutting test protocols and criteria tailored to airfield asphalt mixtures, supporting the Federal Aviation Administration's (FAA's) Balanced Mix Design (BMD) efforts at both the mix design and production stages. Four rutting test methods were evaluated, emphasizing laboratory protocols that best simulate field conditions by accounting for specimen preparation, air void (AV) levels, aging, conditioning, and test temperatures.

Experimental results revealed strong correlations between the Asphalt Pavement Analyzer (APA) at both 100 psi/100 lb and 250 psi/250 lb settings, the high temperature indirect tensile strength test, and the ideal rutting test. Improved correlations were observed when using Hamburg wheel-tracking test rut depths at 5,000 passes rather than 20,000 passes. A 7±0.5 percent AV level was recommended for all rutting tests, facilitating specimen preparation.

A mechanistic-empirical approach was applied to refine the FAA's APA 250 psi/250 lb rutting test criterion by accounting for aircraft speed and load. The framework used the 3D-Move Analysis software tool to model pavement responses under varying temperatures, speeds, and loads, generating stress states for realistic field simulations. Resulting rutting performance models quantified mixture sensitivity to operational conditions, leading to revised test criteria for slow/stationary aircraft and general airfield pavements.

Laboratory verification of the recommended criteria was conducted using field cores from airfield sections with known performance. Revised specifications for P-401/P-403 asphalt mixtures are proposed. To expand BMD implementation into production, pilot projects are recommended to validate the proposed protocols and identify practical challenges. Long-term monitoring of sampled pavement sections will further refine correlations between laboratory criteria and in-service performance of airfield asphalt pavements.

Chapter 1. Introduction and Objective

As part of this project, "Balanced Mix Design (BMD): Rutting Performance Tests," several specimen types and test parameters have been evaluated for implementation in the BMD framework for the Federal Aviation Administration (FAA). These parameters, which include representative specimen air voids (AV), specimen preparation method, and test temperature, were selected to best simulate airfield pavement conditions during laboratory mechanical testing. Subsequently, the set parameters were evaluated and refined while taking into consideration the limitations in laboratory experimental practices and specimen preparation methods. Some specimen conditions reflecting actual airfield flexible pavements could not be exactly simulated during specimen preparation for laboratory mechanical testing, necessitating further changes and considerations. These cases included preparing laboratory specimens at low AV levels corresponding to actual in-place density measurements, which required high compaction effort in the laboratory that was likely to generate damage to the aggregate skeleton (Elias, et al., 2024).

Because the prospective rutting test methods and criteria are intended for use during mix design and production, attention should be given to the sample conditions used for quality control (QC) and acceptance. Furthermore, using field cores sampled during production for BMD mechanical testing is one of the potential options for future implementation. If successful, it will allow FAA to save resources such as the number of cores sampled during placement and the associated labor and time.

In summary, the specimen parameters and test conditions that will be recommended for the FAA BMD framework should be tailored to account for three main aspects: actual airfield pavement conditions, limitations in laboratory practices, and practical sampling techniques during production. This memorandum, "Technical Memo 2: Recommendations on Air Void Level for Flexible Airfield Pavements Mechanical Tests," emphasizes the recommended specimen AV level and preparation methods for BMD laboratory mechanical testing based on field and laboratory experimental analyses. This research project targets only the rutting aspect of flexible airfield pavements. The laboratory rutting tests examined for future implementation include the Asphalt Pavement Analyzer (APA) test (AASHTO T 340), Hamburg wheel-tracking test (HWTT) (AASHTO T 324), high temperature indirect tensile test (HT-IDT) (ASTM D6931), and ideal rutting test (IRT) (ASTM D8360) (AASHTO, 2020; AASHTO, 2022; ASTM, 2017; ASTM, 2022).

Asphalt mixture AV data on plant-mixed laboratory-compacted (PMLC) specimens as well as in-place asphalt density (i.e., core samples) data for an array of airport projects were acquired and analyzed by the research team (Allick Jr., Choubane, Kwon, & Hernando, 2018; Aschenbrener, Brown, Tran, & Blankenship, 2018; Kumar, Coleri, & Obaid, 2021). The analysis was presented in "Technical Memo 1: Analysis of In-Place Density Data from Airfield Projects," which was submitted to the project panel on November 22, 2022 (Hajj, et al., 2025a). Eleven airports around the United States with 12 airfield asphalt concrete pavement projects were evaluated in this analysis. For each airfield pavement project, the job mix formulas, laboratory QC and acceptance data, and field reports for mat and joint core density were analyzed to determine the percentage of AV in the asphalt mixtures.

Based on the analyzed airfield project data in Technical Memo 1, the following AV levels for laboratory mechanical testing were identified for further evaluation (Hajj, et al., 2025a):

- Based on in-place mat density:
    - AV level matching the observed median of mat core data for the percentage of AV in the asphalt mixtures (i.e., 4.1 percent): AV level of 4.0±0.5 percent is selected, or
- AV level matching the 75th percentile of mat core data for percentage of AV in the asphalt mixtures (i.e., 5.2 percent): AV level of 5.0±0.5 percent is selected.
    - Based on in-place joint density:
    - AV level matching the 75th percentile of joint core data for percentage of AV in the asphalt mixtures (i.e., 7.7 percent): AV level of 7.0±0.5 percent is selected to maintain consistency with the AV level specified in current standard test methods (e.g., AASHTO T 324, AASHTO T 340, ASTM D8360) (AASHTO, 2020; AASHTO, 2022; ASTM, 2022).

The three AV levels identified for laboratory mechanical testing (two from in-place mat density and one from joint density) are assessed in Table 1 by means of the percent of data covered within each AV range using the empirical cumulative distribution function. In addition, the advantages and disadvantages of implementing each of the identified AV levels were evaluated and summarized by the research team. More details can be found in the previous technical memorandum from this project, “Technical Memo 1: Analysis of In-Place Density Data from Airfield Projects,” dated November 22, 2022 (Hajj, et al., 2025a).

Table 1. Selected AV Levels for Laboratory Performance Testing[a]

AV Level[b]	Dataset	AV_{LL} ≤ Percent of Data ≤ AV_{UL}	Percent of Data ≤ AV_{UL}
4.0±0.5%	Lab QC and Acceptance (PMLC)	53.4	93.5
	Mat Cores	27.6	60.0
5.0±0.5%	Lab QC and Acceptance (PMLC)	6.5	99.9
	Mat Cores	17.6	77.6
7.0±0.5%	Mat Cores	4.8	97.7
	Joint Cores	16.7	71.8

[a]AV_{LL} = AV lower limit; AV_{UL} = AV upper limit.

[b]The ±0.5 percent tolerance may be increased (e.g., ±1.0 percent) for performance test samples used for acceptance during production.

Subsequently, a mini-experiment to study the feasibility of using the identified AV levels was conducted using the IRT (ASTM, 2022). The objective of the mini-experiment was to verify whether target AV levels could be achieved within a reasonable number of gyrations without crushing aggregate particles or damaging the aggregate skeleton structure during specimen compaction.

The research team assessed the impact of AV on laboratory rutting performance of asphalt mixtures by comparing the IRT results of test specimens compacted at different AV levels. The detailed test data were documented and published in a peer-reviewed journal article titled "Developing Representative Test Specimen Conditions for Rutting Mechanical Test Methods of Airfield Pavements" (Elias, et al., 2024). The observed trend was consistent with the asphalt binders used in the three tested airfield asphalt mixtures, however, the deviation in the mixtures' performance was more pronounced at higher AV (i.e., 7 percent) relative to 4 and 5 percent AV. Interestingly, the IRT was able to capture the effect of polymer-modified asphalt binders, particularly at 7±0.5 percent AV range. On the other hand, the IRT results at lower AV levels (i.e., 4 and 5 percent AV) seemed to be more influenced by the aggregates' structure.

The coefficient of variation (COV) of the IRT results—including samples cut to 4 percent and 5 percent AV grouped together—ranged within a maximum of 8 percent for all three tested asphalt mixtures (within laboratory), when the maximum COV within the IRT replicates at 7 percent AV was 11 percent. It should also be noted that a typical single-operator COV less than 10 percent was reported in previous studies for the repeatability of the IRT test results (Zhou, et al., 2019; NAPA, n.d.). In view of the presented results and discussion in the referenced article, the research team selected the following two AV levels for additional mechanical testing: 7±0.5 percent and 5±0.5 percent, where the latter showed similar results to the 4 percent AV and corresponded to the 75th percentile of the mat core AV data (Elias, et al., 2024).

Key Findings

- *Seventy-eight percent of AVs for mat cores are equal to or less than 5.5 percent.*
- *Ninety-eight percent of AVs for mat cores are equal to or less than 7.5 percent.*
- *Seventy-two percent of AVs for joint cores are equal to or less than 7.5 percent.*
- *AV levels of 5±0.5 percent and 7±0.5 percent were selected for further laboratory mechanical testing.*

Chapter 2. Laboratory Compaction Effort

The limitations of laboratory practices and sample preparation are one of the main considerations for future proposed specifications. While field conditions serve as a key reference for identifying appropriate laboratory testing conditions, it is essential to investigate the practicality and effectiveness of any proposed test conditions. For instance, the laboratory compaction effort needed to reach a representative AV level under a certain specimen height is one of the key parameters assessed by the research team. This was done to avoid excessive compaction effort in the laboratory that may cause aggregate breakdown or damage to the mix skeleton during laboratory compaction. This issue may be encountered with asphalt mixtures, especially those with a large nominal maximum aggregate size, that are directly compacted to 62-mm-high specimens for 5 percent or lower target AV levels. The target final specimen height was set to 62 mm for the HWTT, HT-IDT, and IRT versus 75 mm for the APA, as per common test method procedures (AASHTO, 2020; AASHTO, 2022; ASTM, 2017; ASTM, 2022).

The experimental results of plant-produced asphalt mixtures from four different airfield projects indicate that the 7±0.5 percent AV can be achieved within a reasonable number of gyrations at 62 mm, where the locking point was not reached during compaction in most cases. However, for some of the evaluated airfield mixtures at lower AV (i.e., 5±0.5 percent), samples compacted to a 62 mm height required a significantly higher number of gyrations to reach the target density. The required number of gyrations varied from 1.2 to 4.4 times the respective locking point, delineating varying compactibility among the different asphalt mixtures. The gyratory locking point was determined by following the common Georgia Department of Transportation method, which defines the locking point as the number of gyrations at which the same specimen height repeats three consecutive times (Polaczyk, Huang, Shu, & Gong, 2019).

Because a lower compaction effort is desired, the alternative of cutting 62-mm specimens from thicker 165-mm samples was further investigated to reach the 5±0.5 percent target AV level. On the other hand, the APA samples compacted to a 75 mm height reached the 5 percent or 7 percent target AV within a reasonable number of gyrations due to the thicker specimen geometry. Therefore, the cutting technique was examined solely for specimens targeting 5±0.5 percent AV at 62 mm height (i.e., HWTT, HT-IDT, and IRT).

It is recognized that the cutting technique may delay sample preparation in the laboratory; however, efficiency was optimized in this research by cutting two 62±0.5 mm specimens out of a single, 165-mm-high Superpave Gyratory Compactor sample. It was inferred from the range of required gyrations in the laboratory that the alternative of cutting eliminated the excess compaction effort. The low target ranges of AV were achieved at 62 mm after cutting with a reasonable number of gyrations. The maximum number of gyrations needed to reach 165 mm in height corresponded to 1.4 times the locking point, with the locking point not being reached for some mixtures. Detailed results and analysis of the experimental plan are presented in the aforementioned referenced paper (Elias, et al., 2024).

Key Findings

- *Specimens compacted to 7±0.5 percent AV can be directly molded to a height of 62 mm.*
- *Specimens compacted to 5±0.5 percent AV at 62 mm can be cut from a 165-mm-thick sample to avoid excess laboratory compaction effort.*

Chapter 3. Effect of Specimen Preparation

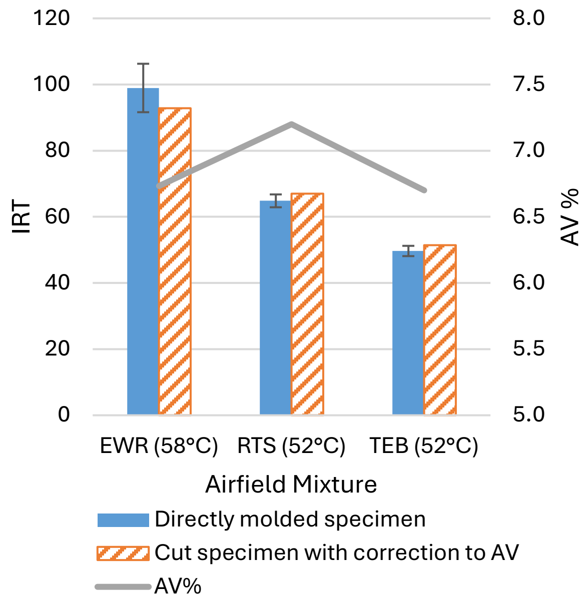
In this section the effect of specimen preparation (e.g., specimens that are directly molded, specimens cut out of a larger sample) on the rutting test results was examined. Rutting tests were conducted at an environmental test temperature representative to the airfield project location. The testing temperature was determined using the Long-Term Pavement Performance Bind (LTPPBind) Online environmental performance grade at the pavement surface, without bumping, with 12.5 mm target rut depth and 50 percent reliability (FHWA, 2024).

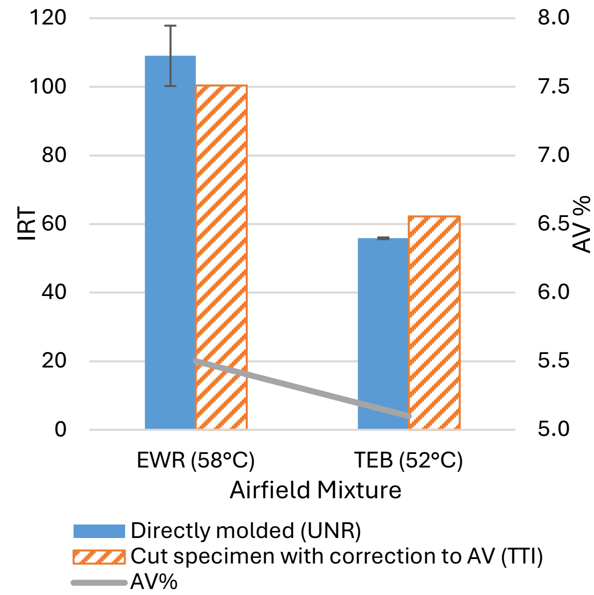
Monotonic Mechanical Test: IRT

As noted, the specimen preparation at 5±0.5 percent AV level involved cutting from thicker samples, assuming that the cutting process would not significantly alter the rutting performance results. Furthermore, the cutting technique needed to be verified to maintain similar mixture rutting resistance; otherwise, the prospective criteria and performance analysis would need to be adjusted between directly molded and cut specimens.

In this regard, the first mini-experiment planned by the research team included replicate specimens from three airfield mixtures targeting 7±0.5 percent AV prepared after direct molding to 62 mm as well as after cutting from 165 mm molded samples. This experimental verification was based on the IRT results of the three mixtures with different specimen preparation methods (directly molded versus cut specimens) targeting 7±0.5 percent AV. Figure 1 shows that the same ranking against rutting resistance was achieved in both specimen types, suggesting similar IRT values for directly molded and cut specimens. The cutting process did not show a bias toward consistently higher or lower IRT values. Furthermore, the IRT values between directly molded and cut specimens ranged within the 11 percent maximum COV reported in this research.

A second experiment was performed on directly molded as well as cut specimens targeting 5±0.5 percent AV for two airfield mixtures. The directly molded and cut specimens were each prepared and tested by different entities. Thus, the multi-laboratory variability between directly molded and cut specimens ranged from 6 to 8 percent for each of the two AC mixtures, which is lower than the maximum single-operator COV of 11 percent reported for the presented set of data. Despite the excess compaction effort of the directly molded specimens, the IRT did not significantly change between both specimen types at the range of 5±0.5 percent AV. Directly molded samples necessitated 98 to 146 gyrations to reach the target AV at 62 mm, corresponding to 2.0 to 3.5 times the relative locking point. Based on the similar results in Figure 2 between both specimen types (at 5 percent and 7 percent AV), it can be concluded that IRT can be consistently conducted either on directly molded or on cut specimens, if needed, without an expected significant difference in the measured relative rutting performance.





EWR = Newark Liberty International Airport; RTS = Reno Stead Airport; TEB = Teterboro Airport; UNR = University of Nevada, Reno; TTI = Texas A&M Transportation Institute.

Source: University of Nevada, Reno

Figure 1. Effect of Cutting at 7±0.5 Percent AV on IRT

Source: University of Nevada, Reno

Figure 2. Effect of Cutting at 5±0.5 Percent AV and Multi-Lab Variability of IRT

Key Findings

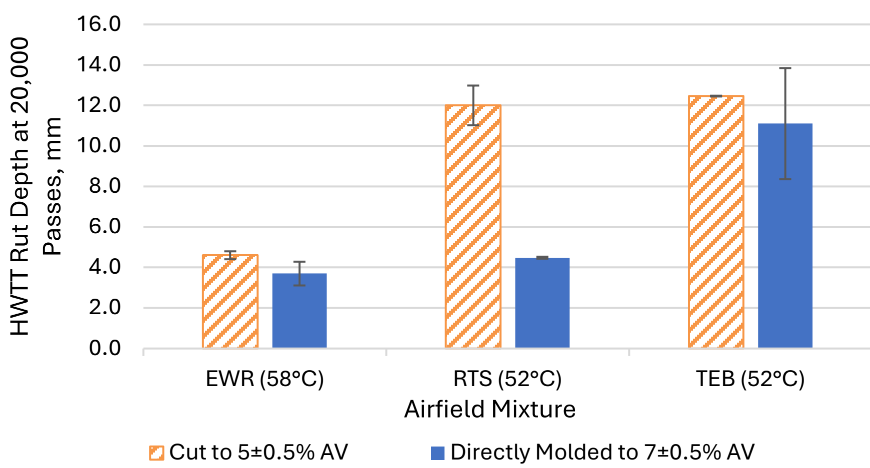
The specimen preparation methods (directly molded versus cut specimens) did not alter or bias the IRT results. Therefore, the IRT can be consistently run on both specimen types without affecting the relative rutting performance.

Repeated-Load Mechanical Test: HWTT

In the case of the APA, the samples with a 75-mm final height reached both target AV levels of 5 percent and 7 percent within a reasonable number of gyrations. Therefore, APA samples at 75-mm final height were directly molded for both target AV levels without the need for cutting when evaluating the effect of AVs on test results.

For the HWTT results, inconsistent trends were noticed among samples with different AV percentages and different preparation methods. Samples at 5 percent AV showed in some cases unexpectedly higher rut depths relative to the 7 percent AV samples, suggesting that cutting had a significant impact on HWTT results. The HWTT was run on two types of laboratory-mixed laboratory-compacted (LMLC) samples: 1) samples cut to 62 mm out of a 165-mm specimen targeting 5±0.5 percent AV (after cutting) and 2) samples directly molded to 7±0.5 percent AV. It is worth mentioning that the HWTT was run under water in wet conditions to control the target test temperature in accordance with the test method. With the aim of maintaining representative surface texture under the wheel in the HWTT, cut specimens at 5±0.5 percent AV were tested while placing the cut face at the bottom and the uncut surface under the wheel.

Nevertheless, high variability and unorthodox trends were observed when testing cut specimens under wet conditions. The effect of AV gradient in the samples after cutting and the porewater pressure confined within cut specimens highly impacted HWTT results, denoting the high impact of specimen preparation method on the HWTT data. This was demonstrated in the example of three airfield mixtures in Figure 3, where samples cut at 5 percent AV showed higher rut depth than samples directly molded to 7 percent AV. Stripping failure was observed in many of the cut specimens due to the water infiltration, leading to the high rut depths and irrational trends of rut depth with AV level.



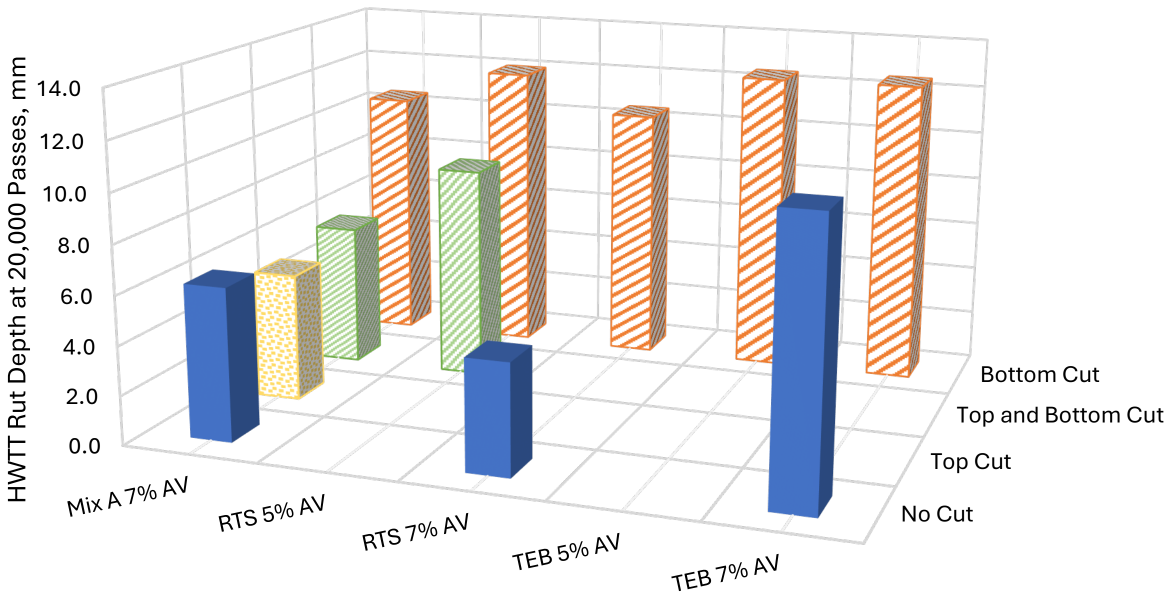
Source: University of Nevada, Reno

Figure 3. HWTT Rut Depth at 20,000 Passes for 5 Percent AV (Cut from Thicker Specimen) and 7 Percent AV (Directly Molded Specimen)

Additional specimen preparation methods were investigated with the HWTT using two airfield mixtures (RTS and TEB) and a highway mixture denoted as Mix A. The different specimen types examined included the following:

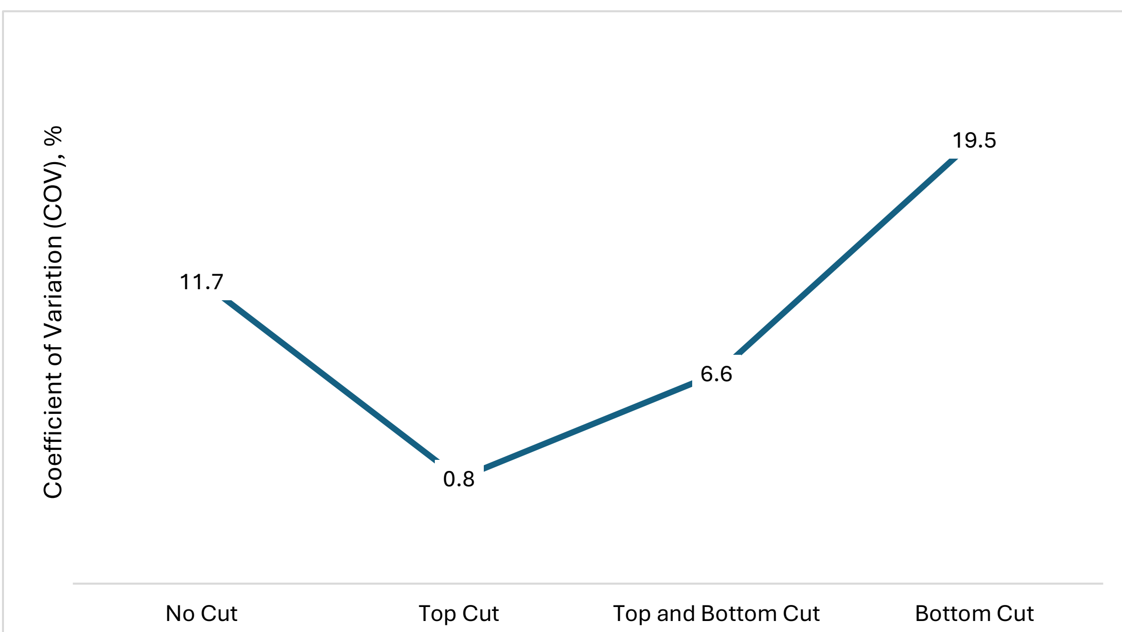
- No cut: HWTT is performed on directly molded samples (no surface cut).
- Top cut: The cut surface of the compacted sample is placed under the HWTT wheel.
- Top and bottom cut: Both sides of the compacted sample are cut.
- Bottom cut: The uncut surface of the compacted sample is placed under the HWTT wheel.

Figure 4 clearly indicates that bottom-cut samples showed consistently higher rut depths than other specimen types, and high variability in the test results (Figure 5), leading to the unexpected trends of rut depth with AV.



Source: University of Nevada, Reno

Figure 4. HWTT Rut Depth with Different Specimen Preparation Methods



Source: University of Nevada, Reno

Figure 5. HWTT COV with Different Specimen Preparation Methods

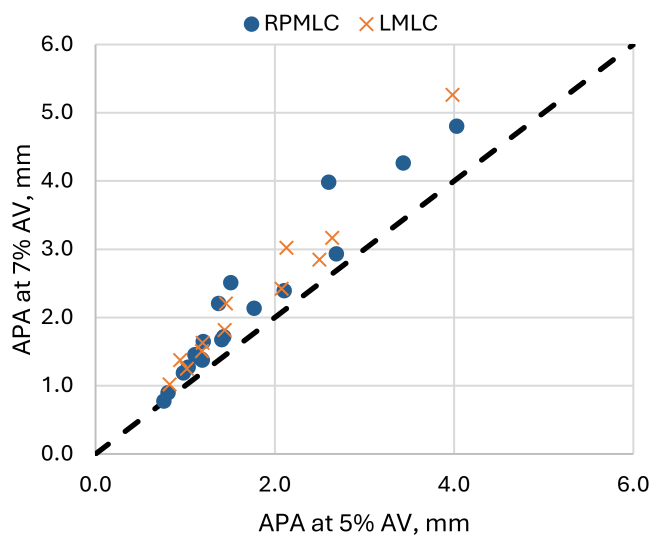
Key Findings

- *Specimen preparation methods showed a significant impact on HWTT results and variability.*
- *For consistent results, HWTT should be conducted on directly molded samples at 7±0.5 percent AV.*

Chapter 4. Effect of Specimen AV Level

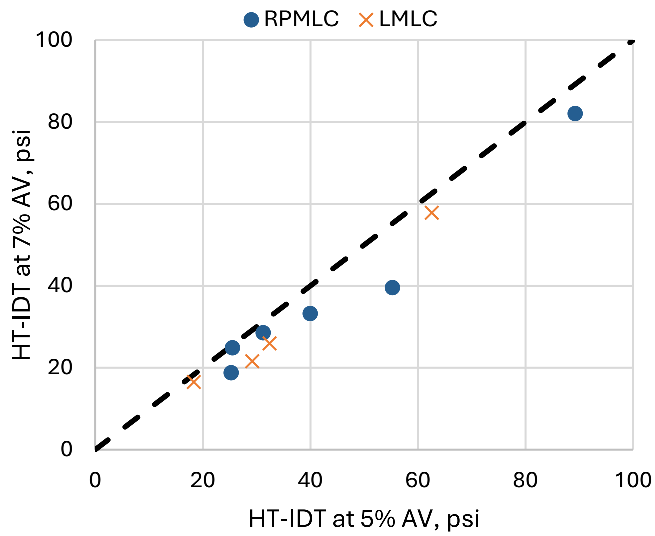
Based on the aforementioned analyses and key findings, the subsequent results represent the full experimental plan data, including LMLC and reheated PMLC (RPMLC) samples of several airfield mixtures at both AV levels: 5±0.5 percent AV (cut specimens) and 7±0.5 percent AV (directly molded). However, in the case of the APA, the samples with a 75-mm final height reached both target AV levels of 5 percent and 7 percent within a reasonable number of gyrations. Therefore, APA samples at a 75-mm final height were directly molded for both target AV levels without the need for cutting during sample preparation.

Figure 6 through Figure 8 indicate robust trends of rutting parameters at both AV levels for APA, HT-IDT, and IRT. As expected, the 5-percent AV samples consistently outperformed the 7-percent AV target samples, indicating that the APA and both monotonic tests can be further simplified to a single AV level for ease of implementation.



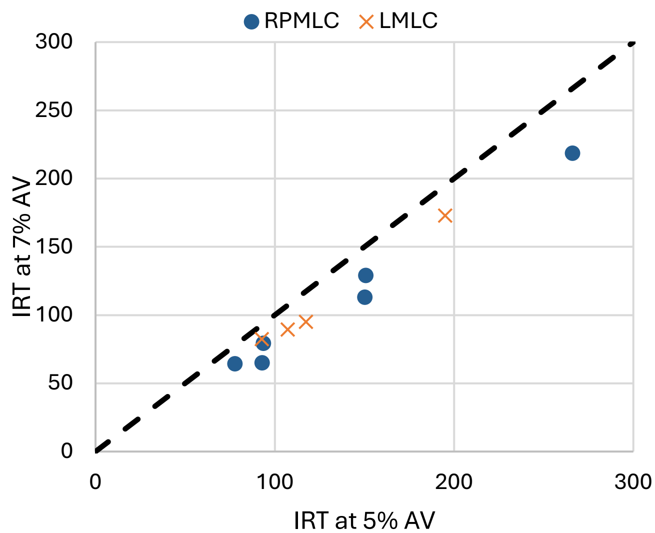
Source: University of Nevada, Reno

Figure 6. APA at 7 Percent AV vs. 5 Percent AV



Source: University of Nevada, Reno

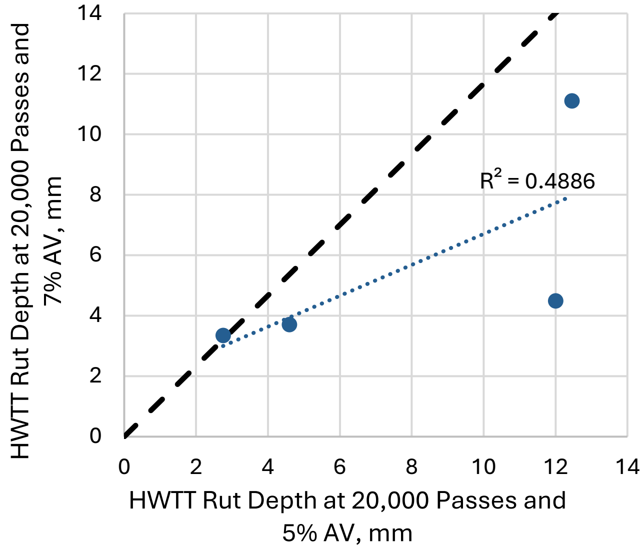
Figure 7. HT-IDT at 7 Percent AV vs. 5 Percent AV



Source: University of Nevada, Reno

Figure 8. IRT at 7 Percent AV vs. 5 Percent AV

On the other hand, no clear correlation was observed for the HWTT results at the two AV levels (see Figure 9). This was expected due to the high variability and inconsistent HWTT results outlined with different specimen preparation methods, as demonstrated in Figure 4. The results suggest again the significance of recommending the HWTT only with directly molded samples at 7±0.5 percent AV with the aim of avoiding inconsistent results due to water infiltration and stripping failure with cut specimens.

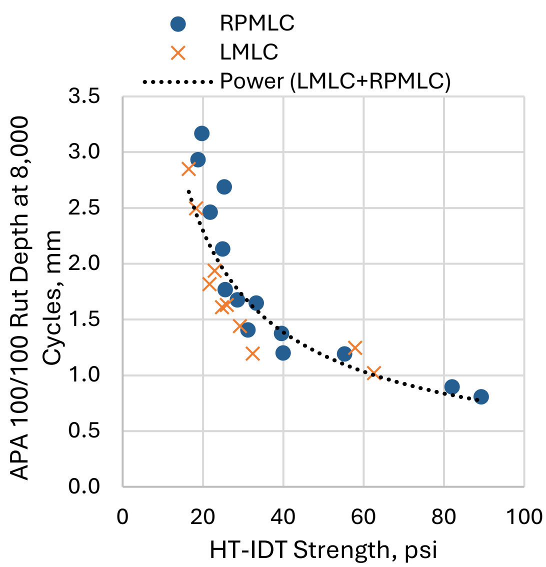


Source: University of Nevada, Reno

Figure 9. HWTT After 20,000 Passes at 7 Percent AV vs. 5 Percent AV

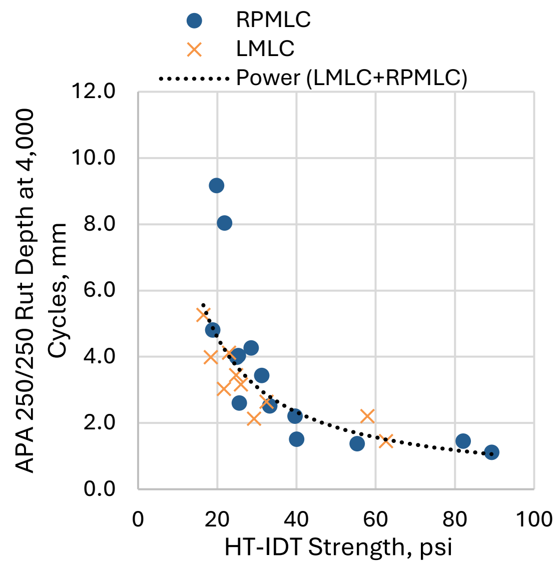
Chapter 5. Rutting Test Correlation

The following section outlines the relationships among different rutting mechanical tests including both suggested AV levels (i.e., 5 percent and 7 percent). Interestingly, the APA results at both loading conditions (i.e., 100 psi/100 lb and 250 psi/250 lb) showed a strong correlation with the HT-IDT and IRT, as shown in Figure 10 through Figure 13. Moreover, a robust trend was observed between both monotonic tests: the HT-IDT and IRT (see Figure 14). The results confirm the suitability of using HT-IDT or IRT in conjunction with the APA test or as surrogate rutting tests during production.



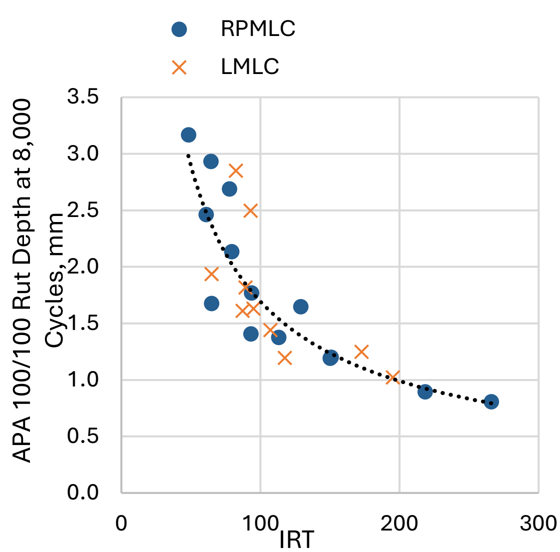
Source: University of Nevada, Reno

Figure 10. APA 100 lb/100 psi at 8,000 Cycles vs. HT-IDT



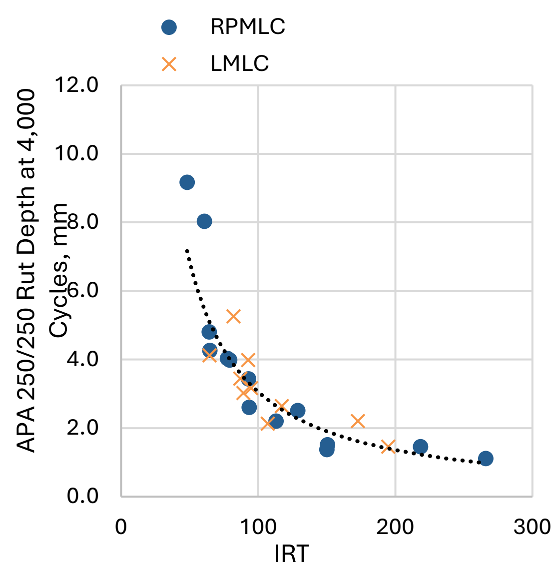
Source: University of Nevada, Reno

Figure 11. APA 250 lb/250 psi at 4,000 Cycles vs. HT-IDT



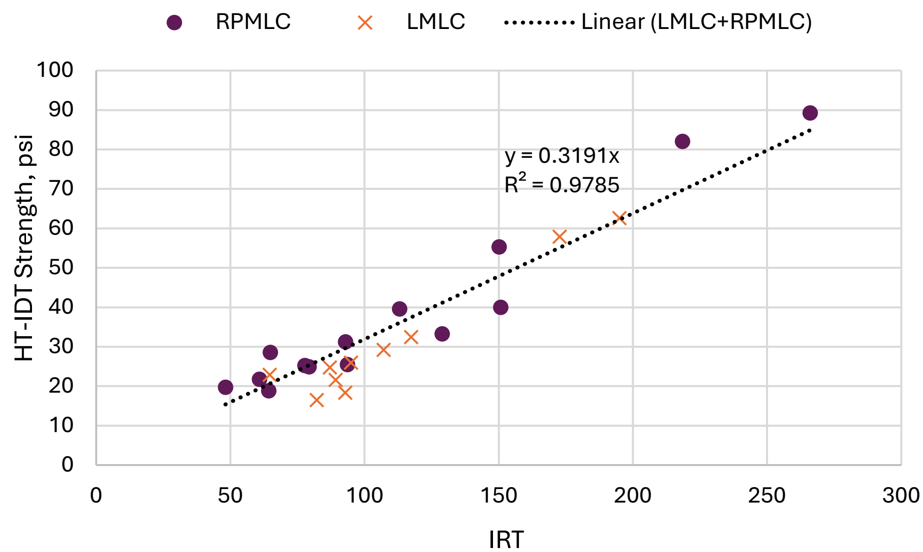
Source: University of Nevada, Reno

Figure 12. APA 100 lb/100 psi at 8,000 Cycles vs. IRT



Source: University of Nevada, Reno

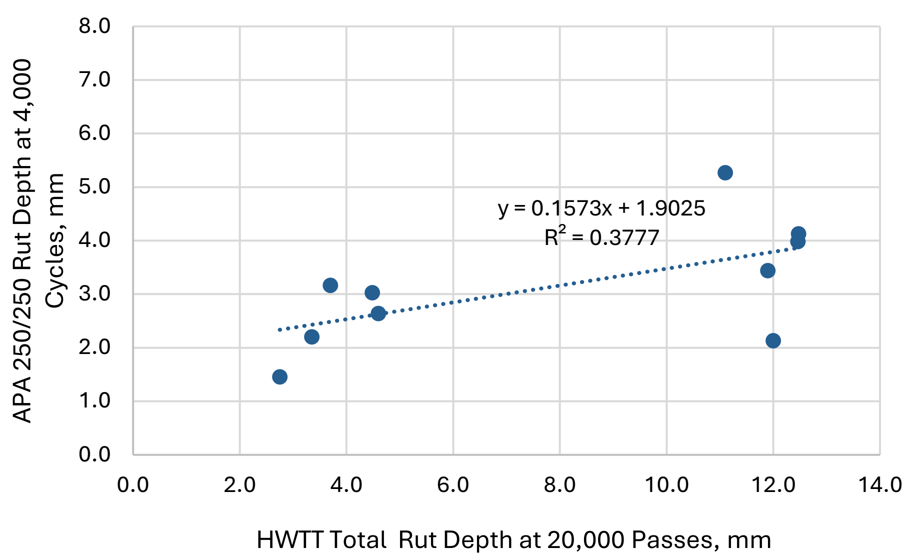
Figure 13. APA 250 lb/250 psi at 4,000 Cycles vs. IRT



Source: University of Nevada, Reno

Figure 14. HT-IDT vs. IRT

Conversely, the HWTT results, including directly molded specimens at 7 percent AV and cut specimens at 5 percent AV, did not hold robust or clear trends compared with the other laboratory mechanical rutting tests. Figure 15 shows an example of the comparison between the HWTT and APA 250 lb/250 psi test results. The data were influenced by the variability of the HWTT results for cut specimens. Thus, demonstrating the impracticality of testing compacted specimens to 5±0.5% AV in the HWTT under wet conditions.



Source: University of Nevada, Reno

Figure 15. APA 250 lb/250 psi at 4,000 Cycles vs. HWTT at 20,000 Passes for LMLC Samples

Chapter 6. Implementation Scenarios

It is commonly acknowledged that recommendations for new test specifications should be carefully set in terms of test criteria as well as test conditions and sample preparation methods, while considering any potential challenges that may arise during implementation. These challenges should be assessed at the three main stages of implementation: mix design, initial production (e.g., control strip), and acceptance during final production. Potential challenges may include excessive laboratory compaction effort needed, long sample preparation and testing times during production, high test result variability, and inconsistent outcomes from different rutting tests.

The FAA currently requires a control strip of at least 250 tons (227 metric tons) or half a sublot, whichever is greater, for airfield asphalt mixtures (Item P-401) (FAA, 2018). Per FAA advisory circular (AC) 150/5370-10H, the control strip shall be placed in two lanes of the same width and depth to be used in production with a longitudinal cold joint (FAA, 2018). The P-401 control strip will be considered acceptable by FAA if gradation, asphalt content, and voids in mineral aggregates are within the action limits specified in AC 150/5370-10H and the mat density is greater than or equal to 94.5 percent (i.e., 5.5 percent AV), laboratory AVs are 3.5 percent ±1 percent, and joint density is greater than or equal to 92.5 percent (i.e., 7.5 percent AV) (FAA, 2018).

According to the analyses in the previous sections and the relationships between varying rutting laboratory mechanical tests, different AV scenarios are recommended for the prospective update of FAA AC 150/5370-10H specifications for airfield asphalt mixtures. The three proposed AV percent scenarios are summarized in Table 2 along with corresponding specimen height, AV level, and specimen preparation method for each of the four rutting tests. Subsequently, Table 3 through Table 5 detail the relative pros, cons, and potential solutions for each of the candidate scenarios during the three main implementation stages. It should be noted that HWTT, HT-IDT, and IRT samples targeting 5±0.5 percent AV required cutting from a larger specimen to reach a 62 mm height to avoid excessive laboratory compaction effort. On the other hand, directly molded specimens are used for APA samples at both AV levels, and for HWTT, HT-IDT, and IRT at 7 percent AV.

Table 2. Candidate AV Scenarios and Related Specimen Preparation

Rutting Test (Height)	Scenario 1: 5±0.5% for APA, HWTT, HT-IDT, and IRT	Scenario 2: 5±0.5% for APA, HT-IDT, and IRT (Excluding HWTT)	Scenario 3: 7±0.5% for APA, HWTT, HT-IDT, and IRT
APA (75 mm)	Directly molded specimens	Directly molded specimens	Directly molded specimens
HWTT (62 mm)	Cut specimens	Not considered	Directly molded specimens
HT-IDT (62mm)	Cut specimens	Cut specimens	Directly molded specimens
IRT (62 mm)	Cut specimens	Cut specimens	Directly molded specimens

Scenario 1: 5.0±0.5 Percent for All Four Rutting Tests

Table 3. Pros, Cons, and Potential Solutions for Scenario 1

Stages	Pros	Cons	Potential Solutions
Mix Design (LMLC)	• Consistent AV% for rutting tests of LMLC samples: APA, HWTT, HT-IDT, and IRT. • Consistent AV level with prospective BMD cracking tests.	• Inapplicable for agencies using HWTT due to high variability and inconsistent results (density grading within specimen and porewater pressure buildup during testing). • Cutting required and delayed sample preparation for HWTT, HT-IDT, and IRT.	• Test HWTT specimens at 7% AV to avoid cutting during sample preparation. • Exclude the use of HWTT for rutting evaluation of airfield asphalt mixtures.
Initial Production (Control Strip)	• Consistent AV% for rutting tests of RPMLC samples: APA, HWTT, HT-IDT, and IRT. • Consistent AV level with prospective BMD cracking tests.	• Inapplicable for agencies using HWTT due to high variability and inconsistent results with cut specimens. • Cutting required and delayed sample preparation for HWTT, HT-IDT, and IRT.	• Test HWTT specimens at 7% AV to avoid cutting during sample preparation. • Exclude the use of HWTT for rutting evaluation of airfield asphalt mixtures.
Acceptance	• Consistent AV% for rutting tests of RPMLC samples: APA, HWTT, HT-IDT, and IRT. • Consistent AV level with prospective BMD cracking tests. • High likelihood of RPMLC density samples falling below target AV_{UL} (i.e., ≤5.5% AV) that can be further tested for performance (e.g., 99.9% of RPMLC samples). Note: only applicable for Superpave mix design samples. • Moderate likelihood of mat and joint density cores falling below target AV_{UL} (i.e., ≤5.5%) that can be further tested for performance (e.g., 77.6% and 43.4% of mat and joint cores, respectively).	• Inapplicable for agencies using HWTT due to high variability and inconsistent results with cut specimens. • Weak correlations between HWTT results and different surrogate rutting tests during production. • Delayed testing during production due to cutting samples prior to HWTT, HT-IDT, and IRT. • Low likelihood of RPMLC density samples falling within target AV level and can be further tested for performance (e.g., 6.5% of RPMLC samples). • Low likelihood of mat and joint density cores falling within target AV range that can be further tested for performance (e.g., 17.6% and 17.9% of mat and joint cores, respectively).	• Test HWTT specimens at 7% AV to avoid cutting during sample preparation. • Exclude the use of HWTT for rutting evaluation of airfield asphalt mixtures.

Note: Samples for HWTT, HT-IDT, and IRT require cutting to reach 5±0.5 percent AV.

Scenario 2: 5.0±0.5 Percent for APA, HT-IDT, and IRT

Table 4. Pros, Cons, and Potential Solutions for Scenario 2

Stages	Pros	Cons	Potential Solutions
Mix Design (LMLC)	• Consistent AV% for rutting tests of LMLC samples: APA, HT-IDT, and IRT. • Consistent AV level with prospective BMD cracking tests.	• Inapplicable for agencies using HWTT. • Cutting required and delayed sample preparation for HT-IDT and IRT.	• Unify to single AV% applicable for the four different rutting tests including HWTT, without the need for cutting.
Initial Production (Control Strip)	• Consistent AV% for rutting tests of RPMLC samples: APA, HT-IDT, and IRT. • Consistent AV level with prospective BMD cracking tests.	• Inapplicable for agencies using HWTT. • Cutting required and delayed sample preparation for HT-IDT and IRT.	• Unify to single AV% applicable for the four different rutting tests including HWTT, without the need for cutting.
Acceptance	• Consistent AV% for rutting tests of RPMLC samples: APA, HT-IDT, and IRT. • Consistent AV level with prospective BMD cracking tests. • High likelihood of RPMLC density samples falling below target AV_{UL} (i.e., ≤5.5% AV) that can be further tested for performance (e.g., 99.9% of RPMLC samples). Note: only applicable for Superpave mix design samples. • Moderate likelihood of mat and joint density cores falling below target AV_{UL} (i.e., ≤5.5%) that can be further tested for performance (e.g., 77.6% and 43.4% of mat and joint cores, respectively).	• Inapplicable for agencies using HWTT. • Delayed testing during production due to cutting samples prior to HT-IDT and IRT. • Low likelihood of RPMLC density samples falling within target AV level that can be further tested for performance (e.g., 6.5% of RPMLC samples). • Low likelihood of mat and joint density cores falling within target AV range that can be further tested for performance (e.g., 17.6% and 17.9% of mat and joint cores, respectively).	• Unify to single AV% applicable for the four different rutting tests including HWTT, without the need for cutting.

Note: Samples for HT-IDT and IRT require cutting to reach 5±0.5 percent AV.

Scenario 3: 7.0±0.5 Percent for All Four Rutting Tests

Table 5. Pros, Cons, and Potential Solutions for Scenario 3

Stages	Pros	Cons	Potential Solutions
Mix Design (LMLC)	• Consistent AV% for rutting tests of LMLC samples: APA, HWTT, HT-IDT, and IRT. • Consistent AV% with highway practice, allowing for leveraging existing knowledge and history. • Increase in turnaround time by eliminating the need to cut specimens. • Eliminate the variability of wet HWTT results from cut samples, which are still widely used by several States.	• Inconsistent AV% with prospective cracking performance tests. Thus, the need to target two AV levels.	
Initial Production (Control Strip)	• Consistent AV% for rutting tests of RPMLC samples: APA, HWTT, HT-IDT, and IRT. • Increase in turnaround time by eliminating the need to cut specimens. • Surrogate rutting tests can be used at single AV% between mix design and production.	• Inconsistent AV% with prospective cracking performance tests. Thus, the need to target two AV levels.	
Acceptance	• Consistent AV% for rutting tests of RPMLC samples: APA, HWTT, HT-IDT, and IRT. • Increase in turnaround time by eliminating the need to cut specimens. • Surrogate rutting tests can be used at single AV% between mix design and production. • High likelihood of RPMLC density samples falling below target AV_{UL} (i.e., ≤7.5% AV) and can be further tested for performance (e.g., 99.99% of RPMLC samples). Note: only applicable for Superpave mix design samples. • High likelihood of mat and joint density cores will fall below target AV_{UL} (i.e., ≤7.5%) that can be further tested for performance (e.g., 97.7% and 71.8% of mat and joint cores, respectively).	• Inconsistent AV% with prospective cracking performance tests. Thus, the need to target two AV levels. • Very small likelihood of RPMLC density samples falling within target AV level that can be further tested for performance. • Low likelihood of mat and joint density cores to fall within target AV range that can be further tested for performance (e.g., 4.8% and 16.7% of mat and joint cores, respectively).	• Reduce the AV% testing level for core samples.

Chapter 7: Final Recommendations

Based on the experimental results and analyses presented in the previous sections, testing cut samples at 5 percent AV in the HWTT under wet conditions caused several stripping failures and jeopardized adequate rut depth evaluation. Considering that several agencies are currently running the wet HWTT with the lack of chamber to control test temperature under dry conditions, the following two potential scenarios are considered for final recommendations:

- 5±0.5 percent AV for APA, HT-IDT, and IRT (while excluding the HWTT).
- 7±0.5 percent AV for all four rutting tests: APA, HWTT, HT-IDT, and IRT.

Recommending a 7±0.5 percent AV level for the four rutting tests allows for preparing specimens by directly molding to either 75 mm for APA or 62 mm for HWTT, HT-IDT, and IRT. The tabulated pros and cons for different AV percent scenarios confirm the efficiency of selecting a single AV level for all four different rutting tests to maintain high consistency in cases of using alternate rutting tests between mix design and production stages. Moreover, testing directly molded specimens will expedite the sample preparation method and testing, where time is of essence during production.

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