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Performance Evaluation of Asphalt Mixture Statewide

Performing Organization: Rutgers University

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16. Abstract

Currently, asphalt mixtures are design using volumetric concepts to determine optimum asphalt content levels with no means of verifying mixture performance prior to field production and placement. A new design methodology called Balanced Mixture Design (BMD) promotes the use of evaluating and design asphalt mixture using rutting and fatigue cracking methods and criteria to achieve an optimum asphalt content that will result in an asphalt mixture performing well in rutting and fatigue cracking scenarios – thereby "balancing" the asphalt mixture performance.

A study was conducted using approved New York State Department of Transportation (NYSDOT) approved asphalt mixtures within this BMD procedure. The approved asphalt mixtures were previously designed using volumetric concepts, allowing for a comparison between performance-based design procedures (BMD) and volumetric procedures. The study showed that of the eleven (11) asphalt mixtures evaluated, six (6) of the asphalt mixtures were found to not meet the BMD fatigue cracking based minimum asphalt content. None of the approved asphalt mixtures failed the rutting performance criteria. The data generated in the study also enabled for the recommendation of performance criteria for the High Temperature IDT Strength test for rutting and IDEAL-CT Index test for fatigue cracking.

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EXECUTIVE SUMMARY

Current asphalt mixture design and quality control practices are primarily based on volumetric testing. Although the development and implementation of the Superpave asphalt mixture design system was intended to include asphalt mixture performance tests, due to the complex nature of the test equipment, analysis and software that accompanied the procedures, the performance testing was quickly dropped, resulting in a methodology purely based on volumetric guidance. In the years after Superpave was implemented, a number of asphalt mixture performance tests began to be developed and utilized across the country. Test methods like the Hamburg Wheel Tracker was implemented in Colorado and Texas while the Asphalt Pavement Analyzer was being used in New Jersey and Georgia. Fatigue cracking tests soon followed with Texas and New Jersey adopting the Overlay Tester and California utilizing the Flexural Beam Fatigue. Additional rutting and fatigue cracking tests were soon to follow, creating a “menu” of performance test methods for potential inclusion in asphalt mixture design and evaluation.

The concept of Balanced Mixture Design (BMD) is that the optimum asphalt content of the asphalt mixture is determined by “balancing” the rutting and fatigue cracking performance of the asphalt mixture during the design phase. Performance criteria, established by the state agency for the regional climate and traffic conditions of the state, must be developed prior to the use of the BMD’s performance test criteria.

In this study, eleven (11) NYSDOT approved asphalt mixtures were recreated in the laboratory and had their respective optimum asphalt content verified using the NYSDOT volumetric mixture design requirements and accompanied by performance testing to set a “baseline” for what is believed to be the existing mixture performance. Mixture performance testing was evaluated for fatigue cracking using the SCB Flexibility Index, Overlay Tester, and IDEAL-CT tests while rutting performance was measured using the Asphalt Pavement Analyzer, Hamburg Wheel Tracking test, and the High Temperature Indirect Tensile test. The asphalt content of the asphalt mixture was then varied at -0.5%, +0.5% and +1.0% of optimum asphalt content with the same performance testing also conducted. The plots of asphalt content versus rutting performance and fatigue cracking performance allowed for the determination of where the asphalt mixture’s asphalt content had to be in order to balance the rutting and fatigue cracking performance. The study showed that 5 of 11 asphalt mixtures, designed through the NYSDOT volumetric procedure, were balanced regarding the rutting and fatigue cracking performance. Meanwhile, 6 of the 11 asphalt mixtures had current asphalt contents not meeting the balanced performance (poor fatigue cracking performance). The test study also allowed for the development of performance criteria for both the IDEAL-CT and High Temperature Indirect Tensile Test using NYSDOT specific asphalt mixtures and materials.

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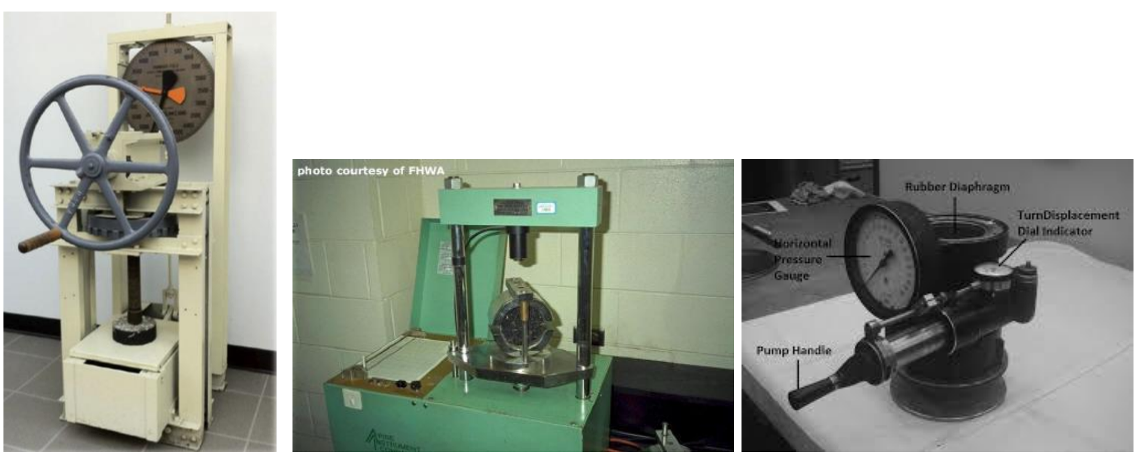
INTRODUCTION

Traditional methods of determining the optimum of asphalt mixtures utilizes volumetric concepts to determine how much asphalt liquid can "fit" within a known volume of space occupied by aggregate and air. Asphalt is mixed with the aggregate and compacted using a predetermined compactive energy to represent traffic levels in the field. The density of the compacted mixture is determined at multiple asphalt contents, along with other volumetric parameters which historically have shown to relate to general field performance. Ultimately, the amount of asphalt liquid required to produce a compacted specimen with a density that is 95 to 97% of the maximum density is selected as the optimum asphalt content. This general approach has been utilized to decades but with different means of compaction depending on the mixture design method.

Various attempts had been made to incorporate asphalt mixture performance testing into the mixture design process. The earliest documented "performance" test was the Hubbard-Field test in the 1920's (Roberts et al., 1996). The test method used a punching shear loading mechanism to evaluate asphalt mixture strength on a compacted mixture or field core (Figure 1a). In the 1930's, two separate mix design methods and "performance tests" were develop for asphalt mixture design. The Marshall method, developed by Bruce Marshall, utilized the impact loading of a Marshall hammer to compact asphalt mixture specimens and then determined the Stability and Flow parameters at a test temperature of 60^{o}C to assess the rutting and cracking potential of the asphalt mixture (Figure 1b). Around the same time, Francis Hveem incorporated the Hveem Stabilometer within his design method to also measure the stability and durability of asphalt mixtures (Figure 1c). In fact, it was Francis Hveem that first developed the concept of a "balanced" area where an optimum range of asphalt contents could provide good rutting and durability properties in asphalt mixtures (Figure 2).



(a) (b) (c)

Figure 1 – Early Performance Tests for Asphalt Mixture Design; (a) Hubbard-Field Stability Test; (b) Marshall Stability and Flow; (c) Hveem Stabilometer

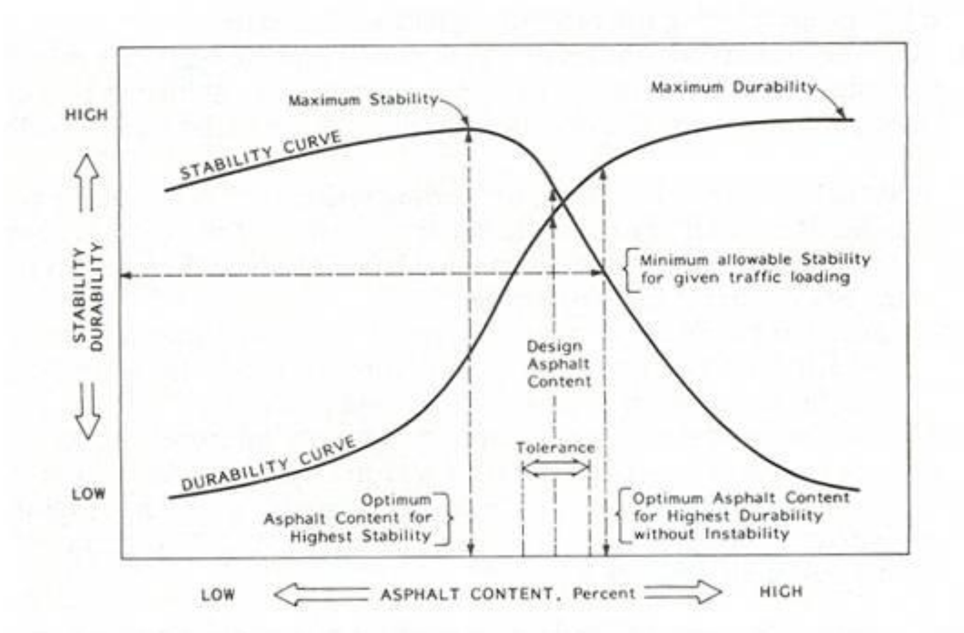


Figure 2 – Proposed "Balanced" Mixture Design Concept from Francis Hveem

In the late 1980's – early 1990's, the Superpave mixture design method was developed utilizing the same volumetric design principles, but for the first time included a suite of test methods to help determine the asphalt mixture performance properties at the selected optimum asphalt content. Mixture stiffness, rutting and cracking potential were proposed to be addressed with a series of test methods with the measured test data capable of predicting field performance when utilized in the Superpave pavement models. Unfortunately, due to sophisticated testing equipment, cost, and time requirements to conduct the performance testing, most viewed the performance testing component of Superpave as too complex and solely incorporated the volumetric portion of the mixture design process. However, it should be noted that many of the proposed performance tests from Superpave are still being utilized to evaluate asphalt mixture performance today.

In the early to mid-2000's, the concept of Performance Related Specifications (PRS) was developed by incorporating a performance test method to address asphalt mixture performance after an optimum asphalt content was determined volumetrically. Performance test criteria for the selected test method are based on field performance observations. One of the first attempts to utilize PRS in asphalt mixture and pavement design was at the WesTrack site. WesTrack was an experimental test road facility located in Nevada and sponsored by the FHWA (Epps et al., 2002). California's Long Life Asphalt Pavement (LLAP) project, which was a multiphase rehabilitation project of the Long Beach Freeway, I-710, in Los Angeles County (Monismith et al., 2008) was one of the very first state agency highway where performance testing was used to design the asphalt mixture and pavement thickness. The researchers used the Superpave Shear Tester (AASHTO T320) and Flexural Beam Fatigue (T321) to develop rutting and fatigue cracking performance for design and acceptance.

What is commonly accepted today as Balanced Mixture Design (BMD) was introduced by Zhou et al (2006). The researchers proposed an integrated approach to mixture design that consisted of testing the asphalt mixture for rutting resistance using the Hamburg Wheel Tracking test, and fatigue cracking using the Overlay Tester at the proposed volumetric optimum asphalt content (Figure 3). The researchers noted that when designed properly, the resultant asphalt mixture will have superior performance over existing volumetric procedures.

The New Jersey Department of Transportation (NJDOT) was one of the first state agencies to include performance testing of asphalt mixtures within their specifications since 2008 (Bennert et al, 2011). Initially, the NJDOT incorporated the Asphalt Pavement Analyzer (AASHTO T340) to ensure the rutting resistance of the High Performance Thin Overlay (HPTO) asphalt mixture used as a pavement preservation surface layer. To date, the NJDOT currently has five (5) different "specialty" asphalt mixtures that require both rutting and fatigue cracking tests to verify performance.

In 2011, Bennert and Pezeshki (2015) initiated a research study that evaluated the asphalt mixture performance of a number of asphalt mixture used in New Jersey. Part of the study included evaluating the BMD approach proposed by Zhou et al (2006) but using test methods adopted by the New Jersey Department of Transportation NJDOT) – Asphalt Pavement Analyzer (AASHTO T340) for rutting and Overlay Tester (NJDOT B-10) for fatigue cracking. The BMD portion of the study clearly showed that asphalt mixtures designed volumetrically in NJ were found to be on the dry side of the range of asphalt

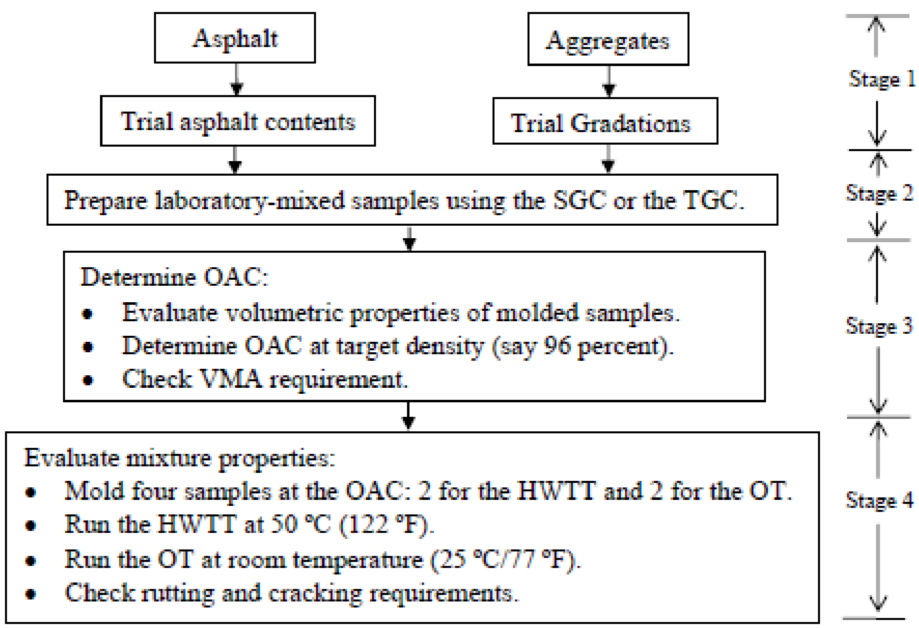


Figure 3 – Proposed Integrated Mixture Design (Zhou et al., 2006)

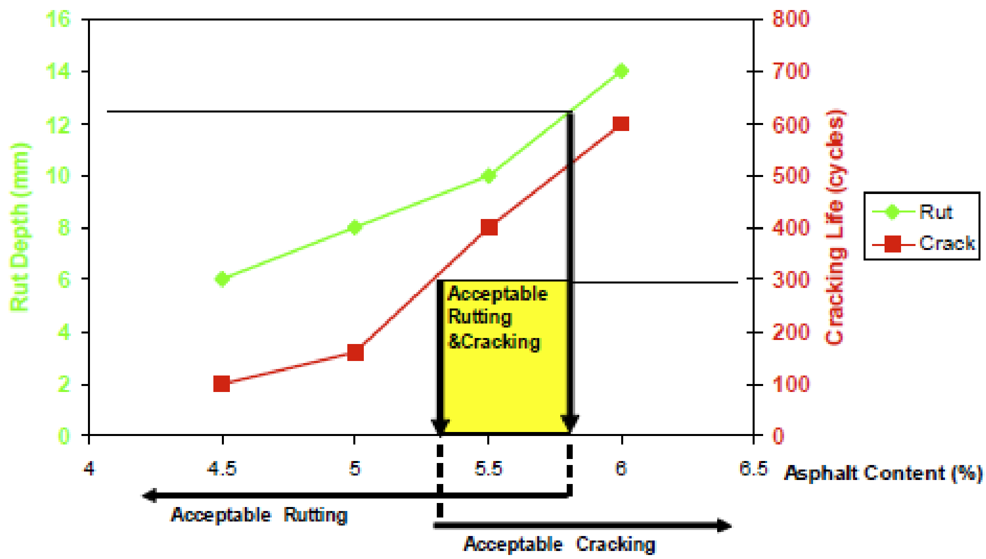


Figure 4 – "Balanced" Area of Asphalt Mixture Performance (Zhou et al, 2006)

contents that "balance" the rutting and fatigue cracking performance of asphalt mixtures for New Jersey materials (Figure 5). The study also clearly showed that utilizing a BMD approach to asphalt mixture design, or verification, can quickly identify deficiencies in the asphalt mixture.

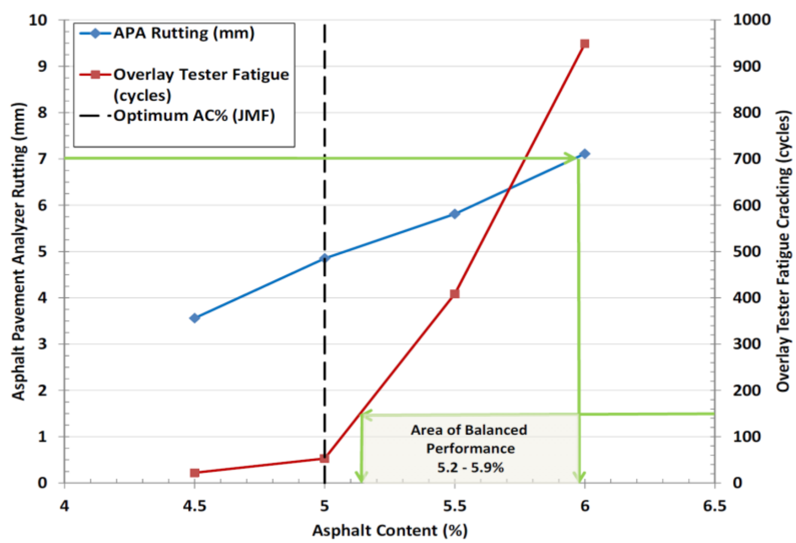


Figure 5 – Balanced Mixture Design Process for a 9.5mm NMAS Asphalt Mixture Using a PG64S-22 Asphalt Binder

Between 2014 and 2020, a number of similar research studies were conducted to evaluate the mixture performance of asphalt mixtures and how volumetrically determined optimum asphalt content compares with performance-based optimum asphalt contents (Cooper et al., 2014; Bennert et al., 2018; Wu et al., 2018; Al-Khayat et la., 2020; Buss et al., 2020; Sreedhar et al., 2020). One particular study conducted by Newcomb and Zhou (2018) looked at helping establish a Balanced Mixture Design framework for Minnesota DOT. In the study, the researchers looked at four (4) asphalt mixtures and evaluated the mixes under the BMD framework that consisted of the following steps:

1. Select the materials (aggregates and asphalt binder) for use according to state agency practice.
2. Combine materials, mix, and short-term oven aged (STOA) for 2 hours at compaction temperature for the rutting tests and long-term oven age (LTOA) for 4 hours at 135°C for the cracking tests.
3. Using the volumetric design, define optimum asphalt content at 4% air voids at a compaction level of N_{design}.
4. Prepare asphalt mixtures at -0.5% Optimum, Optimum, and +0.5% Optimum for performance testing.
5. After conditioning, compact the asphalt mixtures to 7 +/- 0.5% air voids.
6. Conduct cracking and rutting tests.
7. Select the asphalt content define as the Balanced Asphalt Content according to the test results and accounting for the allowable variance of asphalt content during construction. Adding the construction tolerance ensures that the resulting field mixture does not fall below the minimum required by the cracking performance testing.

The researchers noted that the BMD approach was found to be sensitive to the asphalt content of the asphalt mixture and can help a state agency develop better performing asphalt mixtures. However, the cracking and rutting performance criteria in the study needed to be refined for different applications based on characteristics such as climate, lift thickness, traffic level, and placement within the pavement structure.

RESEARCH METHOD

In this study, eleven (11) NYSDOT approved asphalt mixtures from different parts of the state (Figure 6) were evaluated to determine if their volumetrically determined optimum asphalt content was within the "balanced" asphalt content zone where both the rutting and fatigue cracking performance criteria were satisfied at the same time.

The performance tests used in the study included three (3) rutting tests and three (3) intermediate temperature fatigue cracking tests. Each test procedure was conducted in triplicate for each of the BMD selected asphalt contents (-0.5% optimum, optimum, +0.5% optimum and +1.0% optimum). The performance tests included in the study are shown below and discussed in further detail;

- Rutting
    - Asphalt Pavement Analyzer (AASHTO T340)
    - Hamburg Wheel Tracking (AASHTO T324)
    - High Temperature IDT (NCHRP 9-33 Project)
- Fatigue Cracking
    - Overlay Tester (NJDOT B-10)
    - SCB Flexibility Index (AASHTO TP124)
    - IDEAL-CT (ASTM D8225)

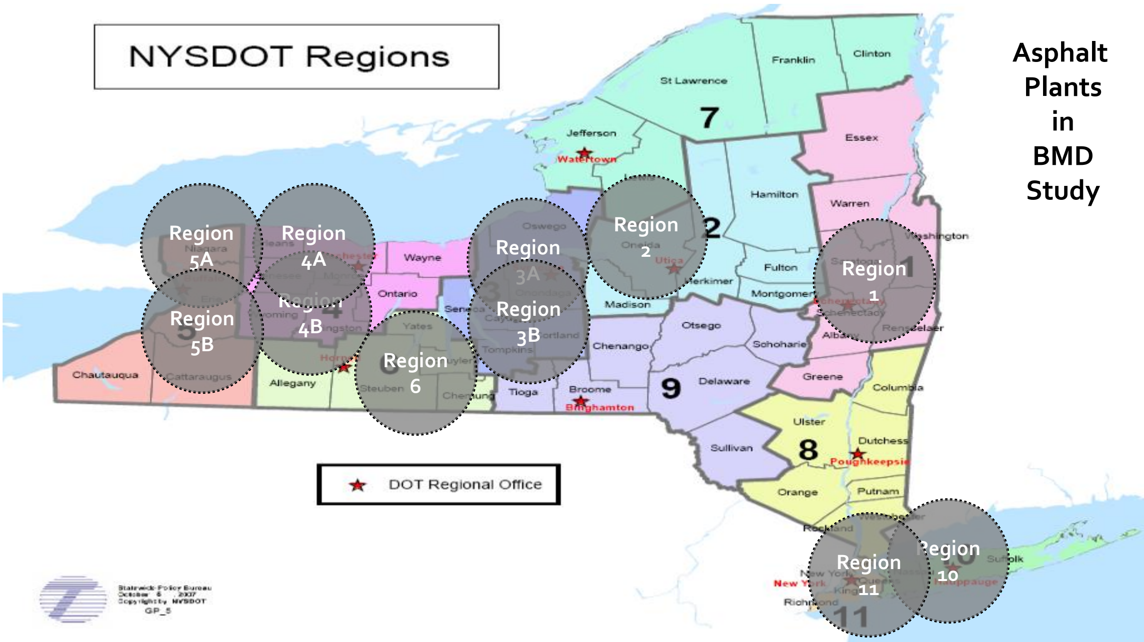


Figure 6 – Regional Locations of Asphalt Mixtures Evaluated in NYSDOT BMD Study

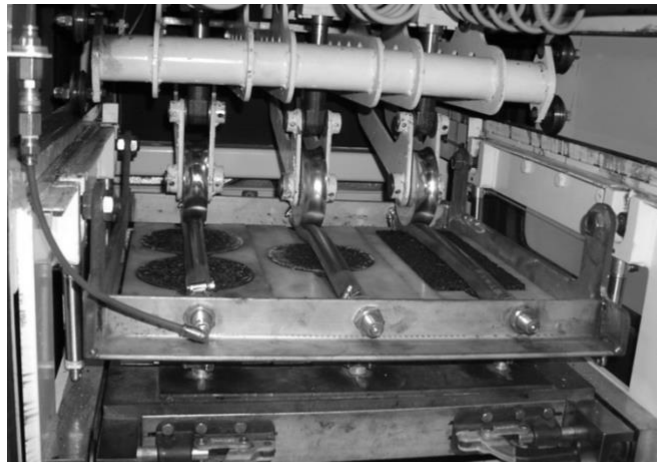
Rutting

For the asphalt mixture rutting tests, after mixing the loose mix was conditioned for 2 hours (+/- 10 minutes) at the respective compaction temperature of the asphalt binder used (i.e. – volumetric conditioning). After conditioning, the asphalt mixtures were compacted to a final test specimen density of 5.5 to 6.5% air voids. This methodology followed that of Newcomb and Zhou (2018).

<u>Asphalt Pavement Analyzer (AASHTO T340)</u>

The Asphalt Pavement Analyzer (APA) was conducted in accordance with AASHTO T340, *Determining Rutting Susceptibility of Asphalt Paving Mixtures Using the Asphalt Pavement Analyzer (APA).* A hose pressure of 100 psi and a wheel load of 100 lb was used in the testing. Testing was continued until 8,000 loading cycles and APA rutting deformation was recorded at each cycle. The APA device used for testing at Rutgers University is shown in Figure 7.

Prior to testing, each sample was heated for 6 hours (+/- 15 minutes) at the testing temperature to ensure temperature equilibrium within the test specimen was achieved. Testing started with 25 cycles used as a seating load to eliminate any sample movement during testing. After the 25 seating cycles completed, the data acquisition began sampling test information until a final 8,000 loading cycles was reached.



(a) **(b)**

Figure 7 - a) Asphalt Pavement Analyzer (APA) at Rutgers University; b) Inside the Asphalt Pavement Analyzer Device

Hamburg Wheel Tracking Test

Rutting potential testing was conducted in accordance with AASHTO T324, *Hamburg Wheel-Track Testing of Compacted Hot-Mix Asphalt (HMA).* This test is utilized to determine the failure susceptibility of a mixture due to weakness in the aggregate structure, inadequate binder stiffness, or moisture damage (AASHTO, 2011). In this test, a mixture is submerged in heated water at 50ºC and subjected to repeated loading provided by a 705N (158lb) steel wheel (Figure 8). As the steel wheel loads the specimen, the corresponding rut depth of the specimen is recorded. The rut depth versus numbers of passes of the wheel is plotted to determine the Stripping Inflection Point (SIP) as shown in Figure 9. The SIP gives an indication of when the test specimen begins to exhibit moisture damage (stripping).

Figure 8 – Post Test Picture of Wet Hamburg Wheel Tracking for Tucson Airport Surface Course

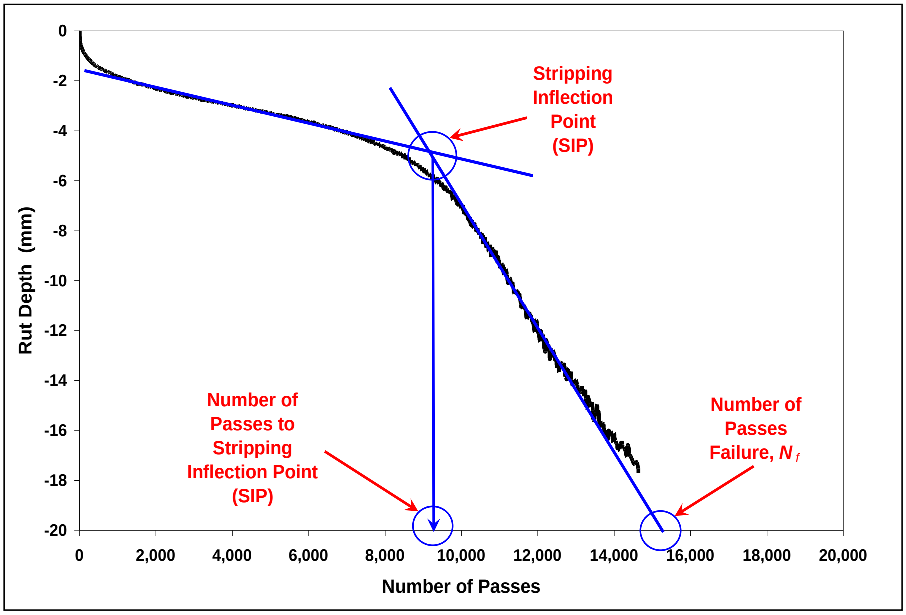


Figure 9 – Determination of HWTD Stripping Inflection Point (SIP)

High Temperature Indirect Tension Test (HT-IDT)

The IDT test was originally developed by Carneiro (1943) when he proposed that the test method could be used to determine the tensile strength of concrete. Similar research was also being conducted in Japan by Akazawa (1943), but due to World War II, published information related to the work in Japan became unvailable. Carneiro (1943) determined that by testing the concrete specimen in a diametral position, a relatively uniform tensile stress develops perpendicular to and along the diametral. Prior to 1962, the IDT test was primarily used for concrete. It was not until after 1962 that other researchers began utilizing the IDT test method for other materials. Livneh and Shklarsky (1962)reported the use of the IDT test to evaluate the anisotropic cohesion of asphalt mixtures. Thompson (1965) began utilizing the test method to evaluate lime stabilized soils and asphalt mixtures. Soon after in 1966, Messina (1966) conducted research at the University of Texas utilizing the IDT procedure to again evaluate asphalt mixtures. In the same year, Breen and Stephens (1966) also began utilizing the IDT procedure to evaluate the low temperature tensile properties of asphalt mixtures. A series of reports conducted by Kennedy and his associates at the University of Texas critically evaluated the IDT test procedure for asphalt materials under both static and dynamic loading conditions and made the IDT an accepted test method to evaluate asphalt mixtures (Kennedy and Anagnos, 1966).

More recently, under the movement to develop a "simple" performance test for asphalt mixtures, researchers again re-evaluated the IDT test and its relationship to various asphalt mixture properties. Gokhale (2001) evaluated the use of the IDT test method to better understand the shear strength properties of asphalt mixtures and concluded that the IDT strength was highly correlated to asphalt mixture cohesion under the Mohr-Coloumb shear strength failure envelope theory. Christensen et al., (2004) found that the IDT test, conducted at a test temperature representative of the critical pavement temperature, was found to be a simple, inexpensive, and effective test for evaluating the rutting resistance of asphalt mixtures. The authors also provided a preliminary threshold values that were developed based on correlations from testing FHWA ALF mixtures. Unfortunately, the final test method required a loading rate of 3.75 mm/min, requiring a more specialized loading system. However, utilizing updated models and test data from NCHRP projects 9-25, 9-31, and 9-33, Christensen and Bonaquist refined the test method to be conducted at 50 mm/min and a test temperature 10^{o}C lower than the yearly, 7-day average, maximum pavement temperature 20 mm below the pavement surface as determined by LTPPBind (Christensen and Bonaquist, 2007; Advanced Asphalt Technologies (AAT), 2011). These changes greatly improved the IDT test, now called High Temperature IDT (HT-IDT), by providing standardized guidance on test temperature, as well as allowing more readily available test equipment to conduct the test. For this study, a test temperature of 44^{o}C was used during the HT-IDT testing.

Fatigue Cracking

For the fatigue cracking tests, after mixing the loose mix was volumetrically conditioned and then conditioned for an additional 4 hours (+/- 10 minutes) at 135°C. The additional conditioning was conducted to accelerate some "aging" in the fatigue cracking asphalt mixture while still be achievable to complete within a single day of work.
This methodology followed that of Newcomb and Zhou (2018).

Overlay Tester (NJDOT B-10)

The Overlay Tester, described by Zhou and Scullion (2007), has shown to provide an excellent correlation to field cracking for both composite pavements (Zhou and Scullion, 2007; Bennert et al., 2009) as well as flexible pavements (Zhou et al., 2007). Figure 10 shows a picture of the Overlay Tester used in this study. Sample preparation and test parameters used in this study followed that of NJDOT B-10, *Overlay Test for Determining Crack Resistance of HMA*. These included:

- 25°C (77°F) test temperature;
- Opening width of 0.025 inches;
- Cycle time of 10 seconds (5 seconds loading, 5 seconds unloading); and
- Specimen failure defined as 93% reduction in Initial Load.

Test specimens were evaluated under both short-term and long-term aged conditions.

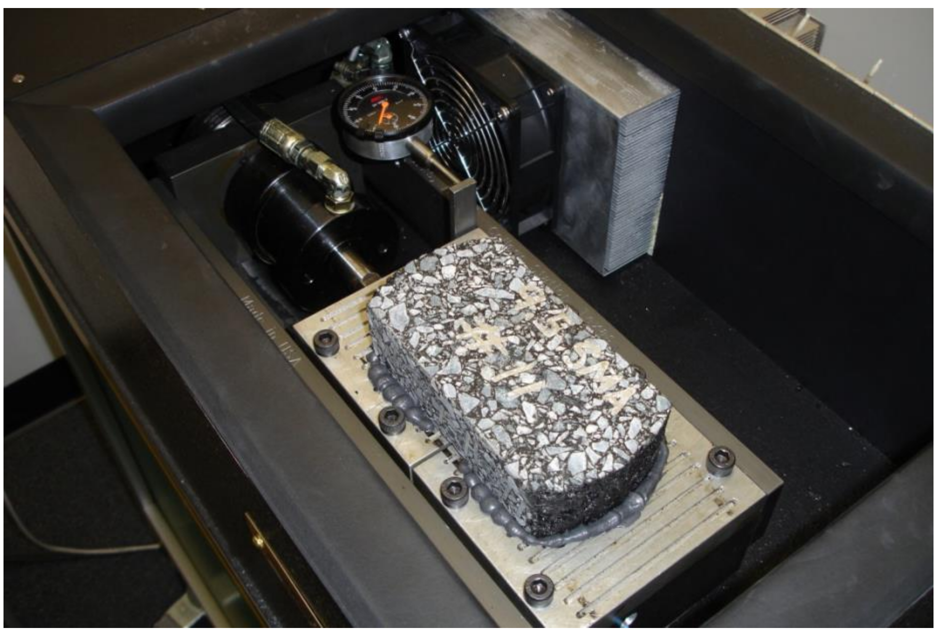
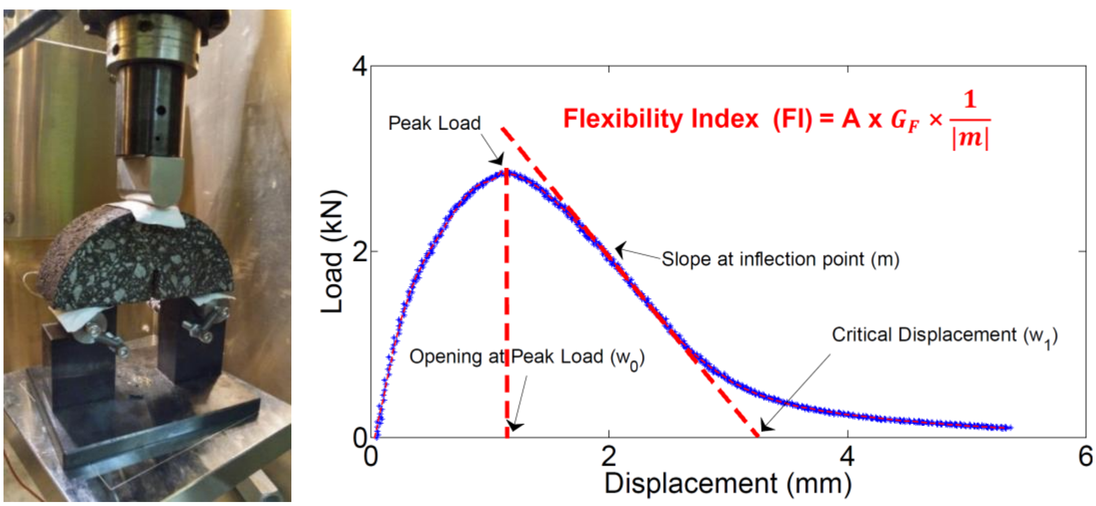


Figure 10 – Picture of the Overlay Tester (Chamber Door Open)

Semi-Circular Bend (SCB) Flexibility Index

The Semi-Circular Bend (SCB) test has been proposed to evaluate the fracture resistance of asphalt mixtures. The general SCB configuration (Figure 11a) has been modified by various researchers in an effort to better understand the fracture resistance properties of asphalt mixtures. Researchers at the University of Illinois utilized the SCB configuration with a slightly different notch depth, loading rate, and data analysis. The final result is a property called "Flexibility Index, FI", which is a composite value consisting of the fracture energy of the specimen, as well as the post-peak strength slope of the Load vs Displacement curve (Figure 11b).

Recent experience by Rutgers University testing field cores from Newark International and JFK International airports has shown that the Flexibility Index (FI) parameter correlated well with cracking distress observed on various runways. Therefore, with the good field correlation, and the fact that there is limited material for testing, it is proposed that only the SCB FI parameter be evaluated in this study.



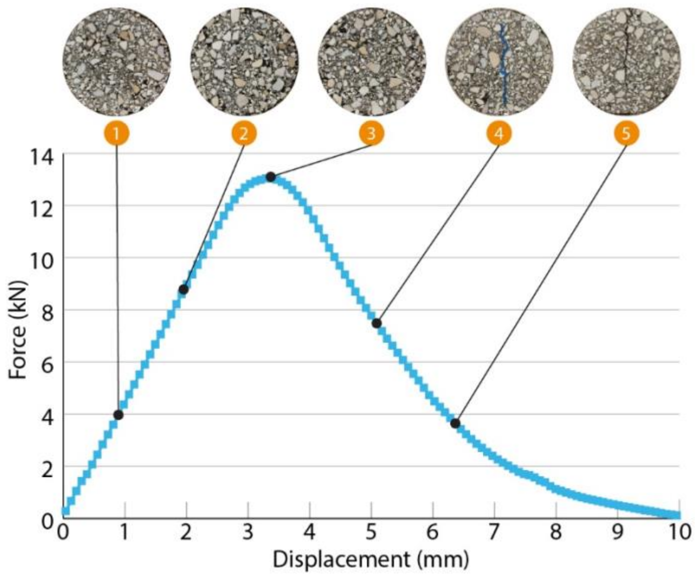
(a) (b)

Figure 11 - Semi-Circular Bend (SCB) Test – (a) Test Equipment; (b) Flexibility Index Calculation

IDEAL-CT Fatigue Cracking Test

The IDEAL-CT is similar to the traditional indirect tensile strength test, and it is run at the room temperature with cylindrical specimens at a loading rate of 50 mm/min. in terms of cross-head displacement. Any size of cylindrical specimens with various diameters (100 or 150 mm) and thicknesses (38, 50, 62, 75 mm, etc.) can be tested. For mix design and laboratory QC/QA, the authors proposed to use the same specimen size as the Hamburg wheel tracking test: 150 mm diameter and 62 mm height, since agencies are familiar with molding such specimens. Either lab-molded cylindrical specimens or field cores can be directly tested with no need for instrumentation, gluing, cutting, notching, coring or any other preparation.

Figure 12 shows a typical IDEAL-CT: cylindrical specimen, test fixture, test temperature, loading rate, and the measured load vs. displacement curve.



Test temperature: 25°C
Loading rate: 50 mm/min.
Specimen: cylindrical specimen without cutting, gluing, instrumentation, drilling, or notching.

Figure 12 - IDEAL-CT: Specimen, Fixture, Test Conditions, and Typical Result

After carefully examining the typical load-displacement curve and associated specimen conditions at different stages (Figure 15), the authors chose the post-peak segment to extract cracking resistance property of asphalt mixes. Note that with the initiation and growth of the macro-crack, load bearing capacity of any asphalt mix will obviously decrease, which is the characteristic of the post-peak segment. The calculation for the cracking parameter, named CT_{Index}, is shown in Equation 3.

$$CT_{Index} = \frac{G_f}{|m_{75}|} \times \left(\frac{l_{75}}{D}\right) \quad (1)$$

where Gf is the energy required to create a unit surface area of a crack; $|m_{75}| = \left|\frac{P_{85}-P_{65}}{l_{85}-l_{65}}\right|$ is the secant slope is defined between the 85 and 65 percent of the peak load point of the load-displacement curve after the peak; and l_{75} is deformation tolerance at 75 percent maximum load.

Generally, the larger the Gf, the better the cracking resistance of asphalt mixes. The stiffer the mix, the faster the cracking growth, the faster the load reduction, the higher the $|m_{75}|$ value, and consequently the poorer the cracking resistance. It is obvious that the mix with a larger $\frac{l_{75}}{D}$ and better *strain* tolerance has a higher cracking resistance than the mix with a smaller $\frac{l_{75}}{D}$.

Performance Testing Criteria for NYSDOT Balanced Mixture Design

Before beginning a Balanced Mixture Design program, performance criteria for the laboratory test methods must be established. The criteria should be determined based on the materials, traffic and climate conditions of the regional area where the performance testing is implemented. In addition, and more importantly, the criteria should correlate to the general field performance observed where those asphalt mixtures are placed (i.e. – as rutting the Asphalt Pavement Analyzer test increases, observed field rutting increases).

For this study, the NYSDOT utilized some existing testing criteria that the NJDOT currently implements for their asphalt mixtures. These are shown in Table 1. Unfortunately, prior to the start of the study, the NYSDOT had not settled on testing criteria for the HT-IDT and IDEAL-CT tests. Therefore, the test data generated during the study was used to develop NYSDOT material specific criteria.

Table 1 – Performance Test Criteria for the Performance Tests Used in the NYSDOT Balanced Mixture Design (BMD) Study

Rutting Test and Criteria	Fatigue Cracking and Criteria
Asphalt Pavement Analyzer < 4.0mm Rutting @ 8,000 cycles and 64^{o}C	Overlay Tester > 250 cycles @ 93% Load Reduction and 25^{o}C
Hamburg Wheel Tracking Test < 12.5mm Rutting @ 20,000 cycles and 50^{o}C	SCB Flexibility Index > 8.0 @ 25^{o}C
High Temperature IDT Strength > 30 psi @ 44^{o}C	IDEAL-CT Index > 135 @ 25^{o}C

To establish the criteria for the HT-IDT, the test results from the Asphalt Pavement Analyzer (APA) and the Hamburg Wheel Tracking (HWT) test were plotted vs the HT-IDT Strength. Since criteria was already established for the APA and HWT, the HT-IDT criteria was determined by averaging the statistical relationship between the test methods. Figures 13 and 14 show the comparisons between the APA and HT-IDT and HWT and HT-IDT, respectively. When averaging the statistical (trendline) relationships between the tests, the resultant HT-IDT criteria is a value of 30.0 psi.

The identical methodology was used for establishing a criteria for the IDEAL-CT test. Figures 15 and 16 show the relationships developed between the Overlay Tester and IDEAL-CT and SCB Flexibility Index and IDEAL-CT, respectively. When averaging the statistical (trendline) relationships between the tests, the resultant IDEAL-CT criteria value is 139. To make this a more even value, an IDEAL-CT Index of 135 was selected.

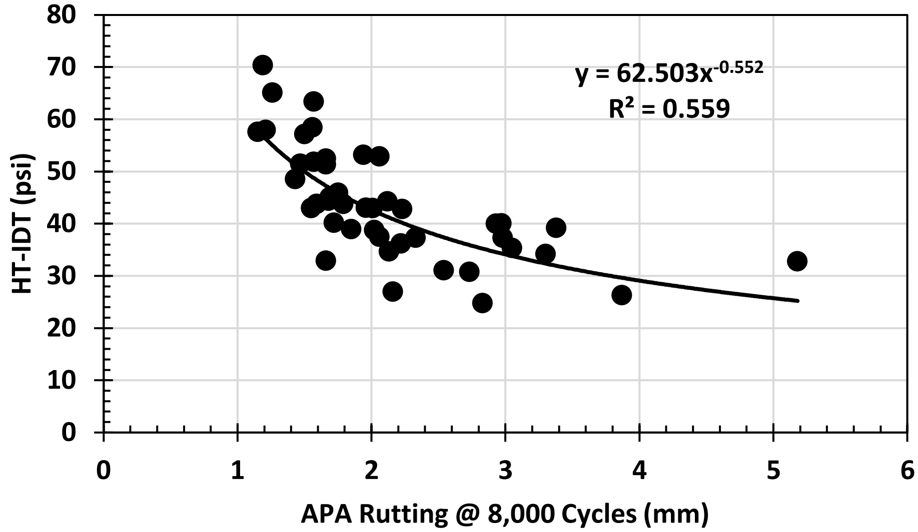


Figure 13 – APA and HT-IDT Relationship Using NYSDOT BMD Asphalt Mixtures

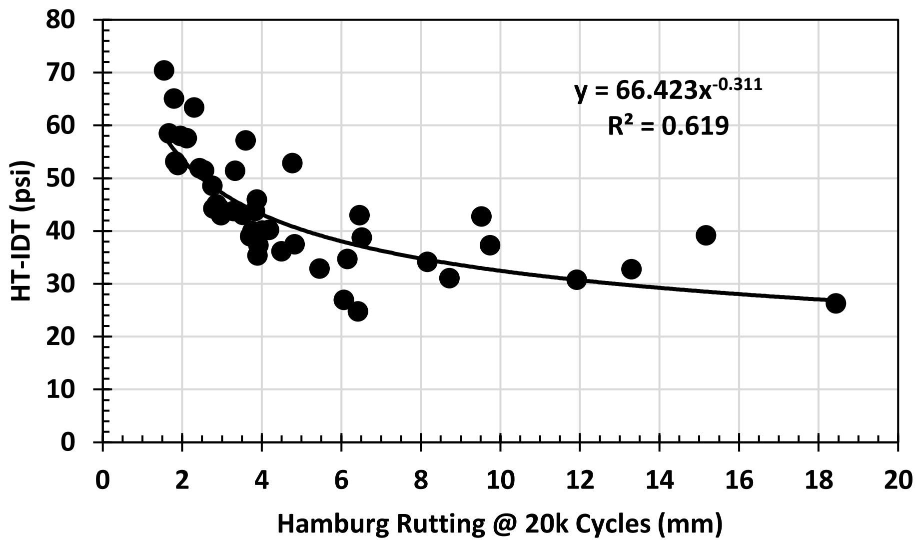


Figure 14 – HWT and HT-IDT Relationship Using NYSDOT BMD Asphalt Mixtures

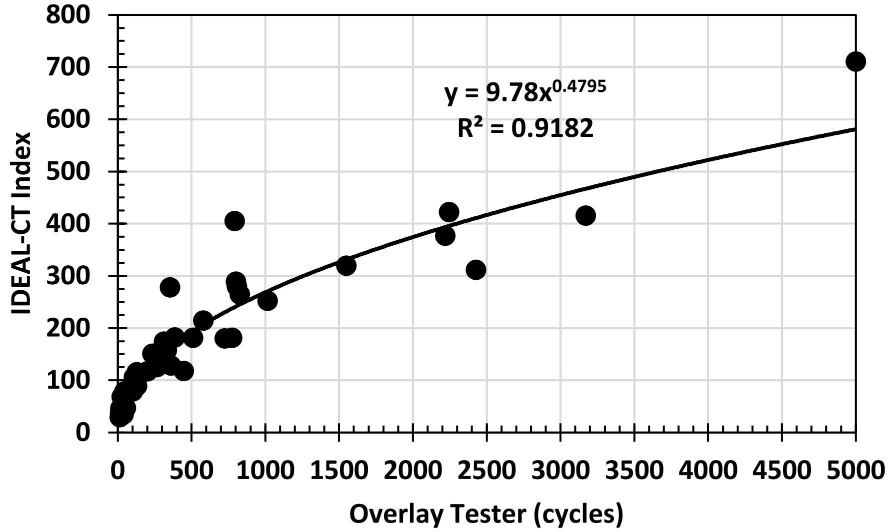


Figure 15 – Overlay Tester and IDEAL-CT Index Relationship Using NYSDOT BMD Asphalt Mixtures

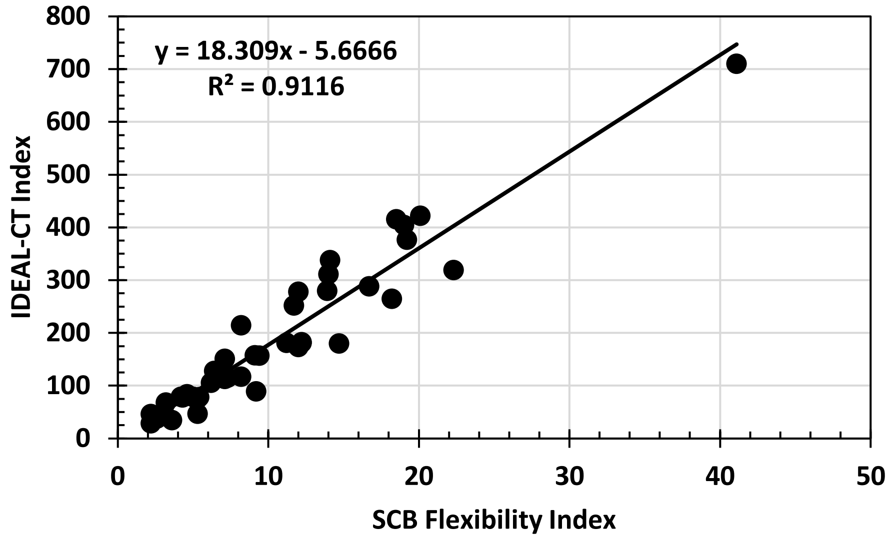


Figure 16 – SCB Flexibility Index and IDEAL-CT Index Relationship Using NYSDOT BMD Asphalt Mixtures

Materials

Eleven (11) NYSDOT approved asphalt mixtures from different regions of the state were selected for evaluation in the study. Table 2 summarizes the asphalt mixture properties provided by the NYSDOT for each of the asphalt mixtures.

Table 2 – NYSDOT BMD Asphalt Mixture Properties

Sieve Size	% Passing										
(mm)	Region 1	Region 2	Region 3A	Region 3B	Region 4A	Region 4B	Region 5A	Region 5B	Region 6	Region 10	Region 11
19	100	100	100	100	100	100	100	100	100	100	100
12.5	99	100	100	100	100	98	100	100	98	100	100
9.5	95	95	99	100	100	84	99	99	93	98	100
No. 4	74	53	80	72	68	56	75	75	63	68	68
No. 8	49	33	50	44	34	36	48	48	33	37	37
No. 16	33	24	31	29	22	23	33	33	24	25	26
No. 30	24	13	16	20	16	15	20	20	17	19	18
No. 50	16	8	9	13	9	10	12	12	9	13	11
No. 100	10	5	6	8	4	6	7	7	6	9	6
No. 200	4.2	4	4	6	2	5	5	5	3	7	4
PG Grade	PG64V-22	PG64V-22	PG64V-22	PG64V-22	PG64V-22	PG64V-22	PG64V-22	PG64V-22	PG64V-22	PG64E-22	PG64E-22
RAP %	20	15	15	10	20	20	15	15	20	20	20
AC %	6.3	6.1	6.2	6.5	6.2	5.5	6.0	6.6	6.0	6.0	6.1
VMA %	15.5	N.A.	16.5	16.1	16.4	15.4	16.2	16.6	N.A.	17.0	16.8
VFA %	77.6		78.2	78.3	76.5	76.8	78.3	77.8		79.6	79.2
Gmm	2.457		2.462	2.427	2.507	2.446	2.435	2.402		2.546	2.461
Gsb	2.629		2.669	2.610	2.714	2.637	2.636	2.596		2.783	2.680

For each of the asphalt mixtures shown, the aggregates and RAP materials were supplied to Rutgers University and tested before the mixtures were verified. For each of the aggregates provided, a washed gradation was conducted in accordance to AASHTO T11, *Standard Method of Test for Materials Finer than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing* and T27, *Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregates*. In addition, the aggregate bulk specific gravity properties were determined in accordance with AASHTO T84, *Standard Method of Test for Specific Gravity and Absorption of Fine Aggregate* and T85, *Standard Method of Test for Specific Gravity and Absorption of Coarse Aggregate*. For the RAP materials provided, the asphalt binder was extracted and recovered in accordance with AASHTO T164, *Procedure for Asphalt Extraction and Recovery Process* using tri-chlorethylene (TCE) as the solvent medium. The asphalt binder content was determined during the extraction process. The asphalt binder was recovered from the TCE solvent in accordance with ASTM D5404, *Standard Practice for Recovery of Asphalt from Solution Using the Rotary Evaporator* (Figure 17). After recovery, the asphalt binder was tested for its respective PG grade, in accordance with AASHTO M320, *Standard Specification for Performance-Graded Asphalt Binder* and Multiple Stress Creep Recovery (MSCR) in accordance with ASTM D7405, *Standard Test Method for Multiple Stress Creep Recovery (MSCR) Test of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)*. The recovered aggregates from the RAP underwent a washed gradation in accordance to AASHTO T30, *Standard Method of Test for Mechanical Analysis of Extracted Aggregate* as well as having their respective aggregate bulk specific gravity determined in accordance to AASHTO T84 and T85. However, it should be noted that the aggregates used for the bulk specific gravity testing were extracted after the ignition oven in order to expedite testing. Results of the RAP testing is shown in Table 3.

Figure 17 – Asphalt Binder Recovery Equipment at Rutgers University

Table 3 – Measured Properties of RAP Material Provided for the NYSDOT BMD Study

Sieve Size (mm)	% Passing										
	Region 1	Region 2	Region 3A	Region 3B	Region 4A	Region 4B	Region 5A	Region 5B	Region 6	Region 10	Region 11
19	100	100	100	100	100	100	100	100	100	100	100
12.5	100	100	100	100	100	100	100	100	100	100	100
9.5	96.0	97.6	97.4	98.3	99.6	98.0	98.3	100.0	98.5	97.6	99.6
No. 4	78.9	68.7	75.5	76.8	89.7	85.8	85.7	89.5	82.6	75.5	78.3
No. 8	59.6	42.1	49.2	48.6	66.4	67.3	62.9	64.1	60.8	56.8	54.9
No. 16	45.6	29.5	34.0	32.4	47.2	47.5	44.2	48.0	44.8	46.3	40.4
No. 30	34.0	21.8	24.6	23.7	33.8	33.6	31.3	34.6	33.3	35.5	29.7
No. 50	22.3	16.7	18.7	18.8	24.8	24.9	22.9	24.5	24.0	20.6	20.1
No. 100	14.6	13.2	14.9	15.4	18.9	19.4	17.9	18.3	17.8	12.2	13.4
No. 200	10.3	10.9	12.2	12.7	14.2	15.5	14.1	13.5	13.0	8.6	9.4
Gsb	2.675	2.608	2.596	2.565	2.593	2.578	2.573	2.575	2.594	2.682	2.794
AC %	5.37	4.78	5.79	5.22	6.23	5.63	5.67	6.31	5.51	4.66	5.07
Continuous HT PG	92.1	87.4	87.9	86.6	82.7	86.2	91.5	90.9	85.5	89.1	88.9
Continuous LT PG	-16.4	-17.3	-17.8	-20.3	-18.6	-16.7	-11.2	-14.6	-15.7	-16.5	-17
Continuous Int PG	32.8	28.9	30.3	25.9	30.5	31.9	38.3	34.4	31.3	32.3	31.5
ΔTc	-5.7	-8.3	-5.2	-6.9	-3.7	-5.8	-6.8	-5.8	-7	-6.6	-5
PG Grade	88-16	82-16	82-16	82-16	82-16	82-16	88-10	88-10	82-10	88-16	88-16

In addition to the aggregates and RAP, the asphalt binder provided was also tested to determine their continuous PG grade and Multiple Stress Creep Recovery (MSCR) properties in accordance to AASHTO M320 and M332, respectively. The performance grading results for the asphalt binders used in the study are shown in Table 4. It should be noted that both asphalt binders provided in the study had a low temperature grade of -28°C, although they were actually supposed to be a -22°C. Asphalt binder grade plays a significant factor in the overall performance of the asphalt mixtures and more robust asphalt binders will generally provide better asphalt mixture performance.

Table 4 – Performance Grade Properties of Asphalt Binders Used in the NYSDOT BMD Study

Target Binder Grade	High Temperature Grade					Intermediate	Low Temp			Continuous PG Grade	AASHTO M332 PG Grade
	Original	RTFO	MSCR				Stiffness	m-value	ΔTc		
			Jnr	% Rec	Elastomer						
PG64V-22	71.1	70	0.821	49.7	PASS	16.5	-30.6	-32.3	1.7	70 -28	PG64V-28
PG64E-22	81.5	79.4	0.144	77.2	PASS	19.6	-28.6	-28.1	-0.5	76 -28	PG64E-28

Asphalt Mixture Verification

The aggregate blends were reproduced using the job mix formula (JMF) percentages noted in the mix design. Aggregate blend percentages were slightly modified if the target aggregate gradation was off by more than +/- 4% on any of the sieve sizes, except for the No. 200 where +/- 2% was used. The RAP content always remained the same percentage as per the job mix formula and determined by mass of the asphalt mixtures.

Before producing the asphalt mixtures for the performance testing, the asphalt mixture volumetrics had to be checked and meet the requirements of the NYSDOT. Table 5 provides the NYSDOT volumetric verification requirements that were met when reconstructing the asphalt mixtures in the laboratory. Asphalt contents were adjusted to ensure the requirements of Table 5 were met if the JMF optimum asphalt content did not meet these requirements.

Table 5 – NYSDOT Asphalt Mixture Volumetric Verification Requirements

Design Criteria/Test Method	Acceptable Tolerance/Variation
Air Voids, V_a (%)	+/- 1.0%
Voids in Mineral Aggregate, VMA (%), for Volumetric Mixes	$VMA_{Table\ 4} - (3.5 - V_{a(lab)})$ when $2.5 \le V_{a(lab)} \le 3.5$ $VMA_{Table\ 4} + (V_{a(lab)} - 3.5)$ when $3.5 < V_{a(lab)} \le 4.5$
Theoretical Maximum Specific Gravity, G_{mm} (g/cm³)	± 0.019
Bulk Specific Gravity of Compacted HMA Specimen, G_{mb} (g/cm³)	± 0.028

Tables 6a through 6d show the JMF and reconstructed (RAPL) volumetrics from the study. The tables show a relatively good consistency between the volumetrics noted in the JMF and what Rutgers University was able to achieve during the reconstruction of the asphalt mixtures. There were some fluctuations with the JMF and the Rutgers determined voids in mineral aggregate (VMA). This was most likely due to differences in the determination of the aggregate blend bulk specific gravity. However, it should be noted that the reconstructed mixes at Rutgers all met the calculated minimum VMA requirements as shown earlier in Table 5.

Table 6 - Comparison Between the NYSDOT Approved JMF Volumetrics and Reconstructed Asphalt Mixture Volumetrics

(a) Asphalt Content

Mix Type	Asphalt Content (%)		
	JMF	RAPL	Diff.
Region 1	6.3	6.8	-0.5
Region 2	6.1	6.1	0.0
Region 3A	6.2	6.8	-0.6
Region 3B	6.5	6.8	-0.3
Region 4A	6.2	6.2	0.0
Region 4B	5.5	5.5	0.0
Region 5A	6	6.1	-0.1
Region 5B	6.6	7.0	-0.4
Region 6	6.3	6.3	0.0
Region 10	6	6.0	0.0
Region 11	6.1	6.7	-0.6

(b) – Maximum Specific Gravity (Gmm)

Mix Type	Gmm (g/cm^3)			Spec Allowance
	JMF	RAPL	Diff.	
Region 1	2.457	2.441	0.016	+/-0.019
Region 2	N.A.	2.467		
Region 3A	2.462	2.459	0.003	
Region 3B	2.427	2.431	-0.004	
Region 4A	2.507	2.502	0.005	
Region 4B	2.446	2.441	0.005	
Region 5A	2.435	2.444	-0.009	
Region 5B	2.402	2.395	0.007	
Region 6	N.A.	2.429		
Region 10	2.546	2.553	-0.007	
Region 11	2.461	2.482	-0.021	

(c) Design Air Voids

Mix Type	Design Air Voids (%)		Spec Allowance
	JMF	RAPL	
Region 1	3.5	4.1	2.5 to 4.5
Region 2	3.5	2.6	
Region 3A	3.5	3.2	
Region 3B	3.5	2.6	
Region 4A	3.5	3.7	
Region 4B	3.5	4.3	
Region 5A	3.5	4.4	
Region 5B	3.5	4.1	
Region 6	3.5	4.1	
Region 10	3.5	3.6	
Region 11	3.5	2.8	

(d) Voids in Mineral Aggregate

Mix Type	VMA (%)			Allowable Min. Based on Table 5
	JMF	RAPL	Diff.	
Region 1	15.5	17.3	-1.8	15.6
Region 2	N.A.	14.6		14.1
Region 3A	16.5	16.0	0.5	14.7
Region 3B	16.1	16.0	0.1	14.1
Region 4A	16.4	15.5	0.9	15.2
Region 4B	15.4	15.5	-0.1	14.8
Region 5A	16.2	16.3	-0.1	15.9
Region 5B	16.6	16.8	-0.2	15.6
Region 6	N.A.	15.6		15.6
Region 10	17.0	15.8	1.2	15.1
Region 11	16.8	17.7	-0.9	14.3

Balanced Mixture Design Results

The Balanced Mixture Design (BMD) performance testing was conducted at four different asphalt contents for each of the asphalt mixtures based on the optimum asphalt content determined in the laboratory. As mentioned earlier, three (3) performance tests were used for rutting and fatigue cracking, respective. The rutting tests were; 1) Asphalt Pavement Analyzer (AASHTO T340), 2) Hamburg Wheel Tracking test (AASHTO T324), and 3) High Temperature IDT (NCHRP 9-33). The fatigue cracking tests were; 1) Overlay Tester (NJDOT B-10), SCB Flexibility Index (AASHTO TP124), and 3) IDEAL-CT Index (ASTM D8225).

The BMD analysis creates an "envelope" of performance where the fatigue cracking dictates the minimum asphalt content and the rutting dictates the maximum asphalt content. Because the NYSDOT has not selected test methods for adoption yet, test methods were arbitrarily selected and coupled with one another to develop the BMD envelope. These were; 1) Asphalt Pavement Analyzer and Overlay Tester (NJDOT test methods); 2) Hamburg Wheel Tracking and SCB Flexibility Index (Illinois DOT test methods), and 3) High Temperature IDT and IDEAL-CT (Quality control test methods).

Due to the number of BMD graphs, the full catalog of plots is shown in Appendix A of the report. Below is an example of the plots so the reader can understand what is being shown (Figure 18). As shown in Figure 18, each BMD graph shows:

1. Rutting test data (black dots) and rutting performance trendline (solid black line);
2. Fatigue cracking data (gray dots) and fatigue cracking performance trendline (solid gray line);
3. Rutting envelope, based on performance criteria for the respective test procedure, constructed using black dotted line;
4. Fatigue cracking envelope, based on performance criteria for the respective test procedure, constructed using gay dotted line;
5. Overlapping rutting and fatigue cracking envelopes define the range of asphalt contents where the asphalt mixture performance is balanced; and
6. Red dotted line represents the volumetrically determined asphalt content. For this study, this is the asphalt content determined at Rutgers University, not from the JMF.

Each of the asphalt mixtures were evaluated for their minimum asphalt content, maximum asphalt content, and range of the BMD condition. The minimum asphalt content was based on the asphalt content to meet the average of the three fatigue cracking tests, while the maximum asphalt content was based on the asphalt content to meet the average of the three rutting tests. The range was calculated by simply subtracting the minimum asphalt content (based on the fatigue cracking results) from the maximum asphalt content (based on rutting results). Table 7 shows the results of the BMD analysis with Table 8 containing detailed information of the resultant asphalt mixture.

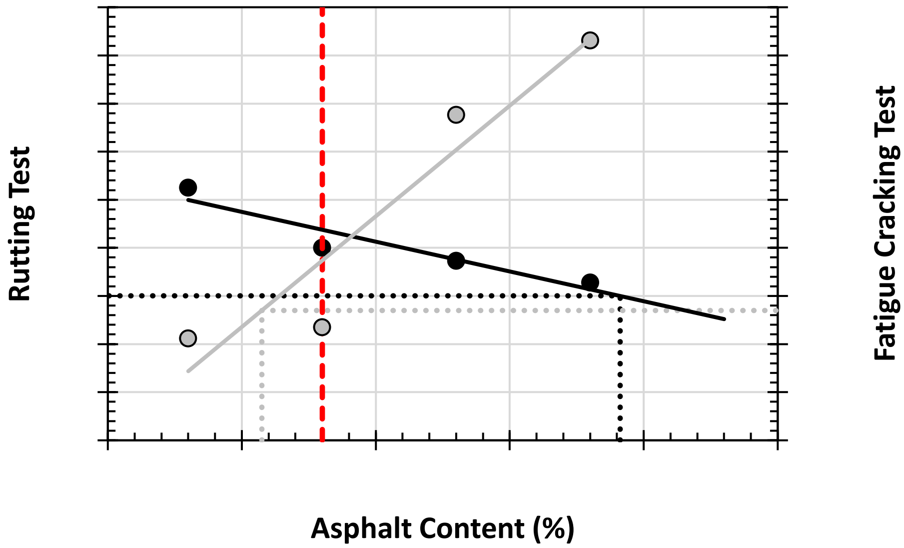


Figure 18 – Example of Balanced Mix Design Graph

Table 7 – Balanced Mixture Design Asphalt Content Properties

Mix Type	Minimum AC% (Ave of Fatigue)	Maximum AC% (Ave of Rutting)	Volumetric Opt AC%	Vol. vs Perform.	BMD AC% Range
Region 1	6.6	7.77	6.8	0.20	1.17
Region 2	5.57	8.26	6.1	0.53	2.69
Region 3A	6.36	9.11	6.8	0.44	2.75
Region 3B	6.67	7.61	6.8	0.13	0.94
Region 4A	6.54	8.66	6.2	-0.34	2.12
Region 4B	5.91	10.61	5.5	-0.41	4.70
Region 5A	6.5	9.83	6.1	-0.40	3.33
Region 5B	7.81	8.32	7.0	-0.81	0.51
Region 6	6.38	8.01	6.3	-0.08	1.63
Region 10	6.39	12.84	6.0	-0.39	6.45
Region 11	6.63	10.21	6.7	0.07	3.58

Table 8 – NYSDOT Mixture Properties with Balanced Mixture Design Properties

Mix Type	Minimum AC% (Ave of Fatigue)	Vol. vs Perform.	BMD AC% Range	NMAS (mm)	Passing No. 4	Passing No. 200	Volumetric Opt AC%	Volumetric Effective AC by Volume (%)	RAP Content (%)	Low Temp PG of RAP	Low Temp PG of Blend	RAP ΔTc	Binder Grade
Region 1	6.6	0.20	1.17	9.5	71.3	4.5	6.8	10.5	20	-16.4	-28.2	-5.7	PG64V-22
Region 2	5.57	0.53	2.69	9.5	52.9	5.4	6.1	8.5	15	-17.3	-29.1	-8.3	PG64V-22
Region 3A	6.36	0.44	2.75	9.5	80.2	7.3	6.8	9.2	15	-17.8	-29	-5.2	PG64V-22
Region 3B	6.67	0.13	0.94	9.5	74.0	6.0	6.8	9.2	10	-20.3	-29.8	-6.9	PG64V-22
Region 4A	6.54	**-0.34**	2.12	9.5	76.2	5.9	6.2	9.3	20	-18.6	-28.2	-3.7	PG64V-22
Region 4B	5.91	**-0.41**	4.70	12.5	60.4	6.8	5.5	10.0	20	-16.7	-27.9	-5.8	PG64V-22
Region 5A	6.5	**-0.40**	3.33	9.5	81.9	5.9	6.1	10.2	15	-11.2	-27.9	-6.8	PG64V-22
Region 5B	7.81	**-0.81**	0.51	9.5	79.1	6.2	7.0	9.8	15	-14.6	-28.5	-5.8	PG64V-22
Region 6	6.38	**-0.08**	1.63	9.5	60.7	4.3	6.3	9.3	20	-15.7	-28	-7.0	PG64V-22
Region 10	6.39	**-0.39**	6.45	9.5	67.9	6.3	6.0	9.8	20	-16.5	-26.2	-6.6	PG64E-22
Region 11	6.63	0.07	3.58	9.5	73.2	3.6	6.7	11.0	20	-17	-26.4	-5.0	PG64E-22

The results in Table 7 indicate that six (6) of the asphalt mixtures evaluated had volumetric optimum asphalt contents below the minimum asphalt content necessary to meet the fatigue cracking criteria. There were no cases where the volumetric optimum asphalt content exceeded the maximum asphalt content to cause the mixture to fail the rutting performance criteria.

When comparing the results, it is also important to consider the relative accuracy of the determining asphalt content of the asphalt mixtures. According to the precision and bias statement of AASHTO T308, Determination of Asphalt Content by Ignition, the allowable range between two results from multiple operators is 0.33% asphalt content. Taking this range into consideration, four (4) of the asphalt mixtures may be classified as "borderline" regarding their respective condition. This occurred for three (3) of the mixtures that met the minimum fatigue cracking asphalt content with only occurring from an asphalt mixture that did not meet the minimum fatigue cracking asphalt content.

Another important factor to consider when evaluating the test data from BMD is the "range" of asphalt content as determined by the difference between the maximum rutting asphalt content and the minimum fatigue cracking asphalt content. A BMD design with a narrow range may be difficult to produce if small deviations from the JMF are not allowed. Meanwhile, the larger the BMD range, the more room the asphalt plant has to make adjustments, as long as the producer maintains asphalt contents that are above or below the performance limits.

Table 8 contains more detailed asphalt mixture information with the BMD critical design parameters. Included in the parameter information are things like total asphalt content by weight, effective asphalt content by volume, RAP content and respective low PG grade, and gradation properties. Initial observations from Table 8 shows that there did not appear to be any significant trends regarding the BMD performance parameters and the mixture properties. This would suggest that greater interactions between properties such as aggregate absorption, aggregate structure, RAP and virgin binder blending may be influencing how the BMD range is created. One can quickly see that the use of the more polymer modified binder (PG64E-22) achieved higher BMD ranges, but there were also cases where the PG64V-22 achieved similar to better. Further research needs to be invested to better understand the inter-relationships between the mixture performance and BMD design parameters.

Regarding the relative comparisons of the different performance tests, as it was shown earlier, the rutting tests and fatigue cracking tests were found to be highly correlated to one another, respectively. However, there is always going to be some small differences between how the test methods may rank the mixes or whether or not the asphalt mixture performance meets the selected criteria. Overall, the Overlay Tester found the minimum asphalt content seven (7) out of the eleven (11) asphalt mixtures, while the SCB Flexibility Index and IDEAL-CT identified the minimum asphalt content three (3) and one (1) time, respectively. Regarding the rutting performance, the High Temperature IDT identified the "lowest" maximum asphalt content eight (8) out of the eleven (11) asphalt mixtures, while the Asphalt Pavement Analyzer and Hamburg Wheel Tracking tests identified the "lowest" maximum asphalt content one (1) and two (2) times, respectively.

Resultant Air Voids at Balanced Mix Design Minimum Asphalt Content

One of the questions commonly asked is if the use of BMD could potentially modify volumetric design parameters in an effort to achieve similar performance. Or, what are the resultant air voids at asphalt contents that are found to be higher than the volumetric optimum? In an effort to answer these questions, the BMD asphalt mixtures were compacted to N_{max} for each of their respective asphalt contents and the N_{des} value backcalculated using Superpave procedures. Mixtures were compacted out to N_{max} as part of the NYSDOT 5.16 Specification requirements.

Figures 19 shows this analysis for the fatigue cracking and rutting performance tests, respectively, for the Region 1 asphalt mixture. In Figure 19, all three (3) of the fatigue cracking tests resulted in the identical asphalt content, which resulted in an air void content of 4.8%. Meanwhile, the volumetric optimum asphalt content was determined at 4.0% air voids. This indicates that the volumetric asphalt content was higher than what was determined as the minimum required asphalt content to meet the fatigue cracking performance. The N_{des} analysis was conducted for each asphalt mixture to show how the fatigue cracking performance minimum asphalt content would have resulted in a volumetric air void level. The detailed curves can be found in Appendix B of the report.

With respect to utilizing the BMD procedure in practice, there are two ways a state agency would most likely implement the BMD determined asphalt content. The first method would be to utilize the fatigue cracking based minimum asphalt content as the JMF "optimum" asphalt content and specify that this is the absolute minimum allowable asphalt content. The second way would be to utilize the fatigue cracking based minimum asphalt content plus 0.4%, which is the allowable asphalt content production tolerance. By including the production tolerance into the BMD minimum asphalt content, the agency can assure they are receiving an asphalt mixture that will always meet the fatigue performance requirement. However, it should be noted that rutting may need to be verified. Figures 20 and 21 show the comparison between the two proposed BMD fatigue cracking minimum asphalt content scenarios, as well as the volumetric for each of the BMD asphalt mixtures.

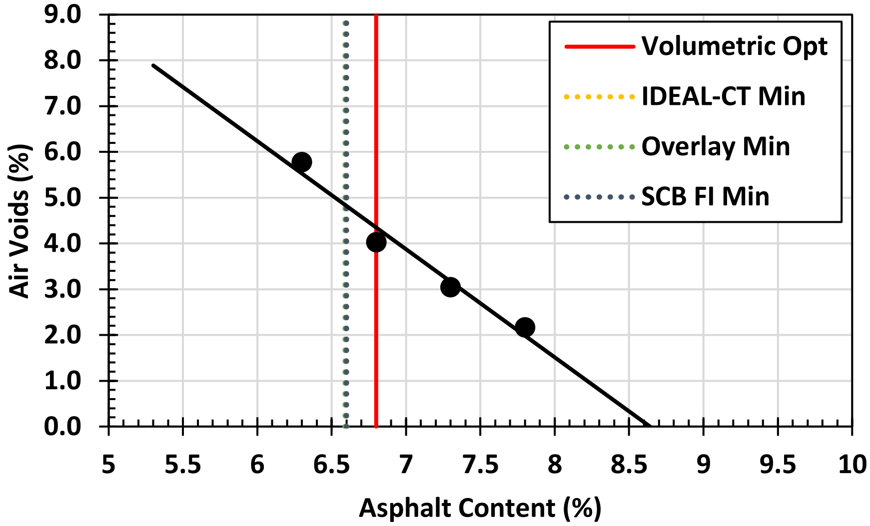


Figure 19 – Resultant N_{des} Air Voids for Region 1 Asphalt Mixture with Minimum Asphalt Contents Determined from Fatigue Cracking Tests

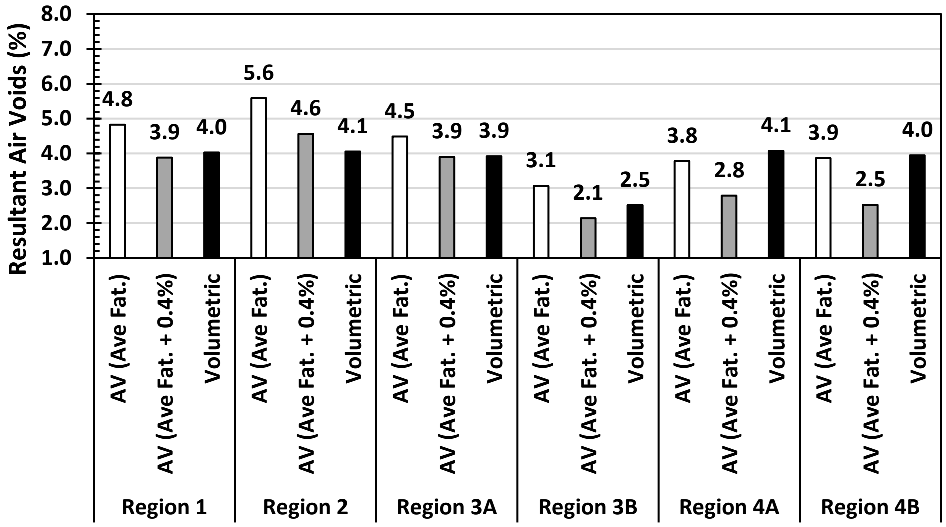


Figure 20 – Calculated Air Voids for Different Asphalt Content Conditions – BMD vs Volumetric – Regions 1 through 4

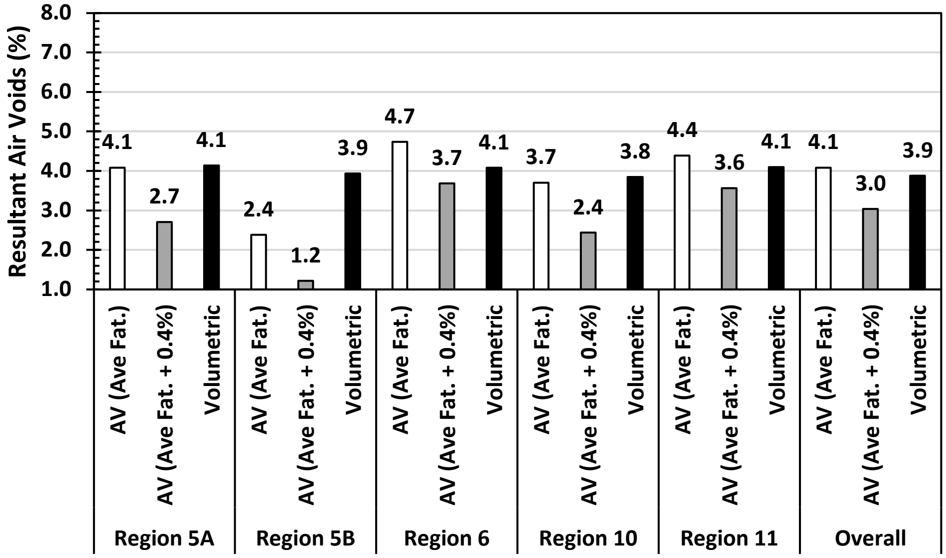


Figure 21 – Calculated Air Voids for Different Asphalt Content Conditions – BMD vs Volumetric – Regions 5 through 11

Overall, what was determined through the analysis was that the theoretical calculated air voids for the average BMD Fatigue Cracking Minimum Asphalt Content (4.1%) was essentially equal to average Volumetric Optimum Asphalt Content. However, it should be noted that the standard deviation and range were TWICE are large for the BMD Fatigue Cracking Minimum Asphalt Content (0.9% and 3.2%, respectively) when compared to the Volumetric Optimum Asphalt Content (0.5% and 1.6%, respectively). What this means is the mix design constituent properties, RAP properties, and asphalt binder properties play a more significant role at achieving a minimum asphalt content to meet fatigue cracking needs than simply determining asphalt content by volumetrics alone.

Similar variability was found when applying the production tolerance asphalt content. If a state agency decided to implement the BMD Fatigue Cracking Minimum Asphalt Content + 0.4% Production Tolerance, the theoretical N_{des} air voids would have been 3.0% with a standard deviation of 1.0% and range of 3.3%.

FINDINGS AND CONCLUSIONS

A study was conducted to evaluate NYSDOT approved asphalt mixtures within a performance-based Balanced Mixture Design (BMD) system. The approved asphalt mixtures, designed and verified using the NYSDOT volumetric design specifications, were tested under three (3) fatigue cracking and three (3) rutting laboratory test methods. Asphalt contents were varied at 0.5% intervals based on the volumetrically determined/verified optimum asphalt content (-0.5% optimum, optimum, +0.5% optimum, +1.0% optimum). The rutting and fatigue cracking performance of the asphalt mixtures, at the different asphalt contents, were plotted against each other to determine a zone where the asphalt content of the asphalt mixture met both the rutting and fatigue cracking performance criteria established in the study. Based on the results generated in the study, the following findings and conclusions were drawn:

- Six (6) of the asphalt mixtures evaluated showed to have asphalt contents too low to achieve the average minimum fatigue cracking performance requirements;
- Five (5) of the asphalt mixtures evaluated showed to have asphalt contents meeting or exceeding the asphalt content requirements needed to meet the minimum fatigue cracking performance requirements;
- None of the asphalt mixtures had issues achieving the rutting requirements at any of the asphalt contents selected, even as high as 1% above the volumetric optimum asphalt content;
- The range between the average BMD rutting and fatigue cracking asphalt contents was found to vary between the eleven (11) different asphalt mixtures and did not appear to be a function of conventional asphalt mixture properties. Larger ranges were noticed when the asphalt binder was more heavily, polymer modified (PG64V-22 vs PG64E-22), but only dataset (2) asphalt mixtures had the PG64E-22 asphalt binder for comparisons.
- The range of the BMD asphalt contents is important to consider regarding the production of the asphalt mixture. Narrow or small ranges could result in difficulties producing asphalt mixtures capable of meeting both performance requirements. Larger ranges provide a greater allowance for production changes without detrimentally impacting the asphalt mixture balanced performance.
- In an attempt to determine an equivalent design air void level from the BMD design process, it was found that an average value of 4.0% air voids was found to meet the minimum fatigue cracking asphalt content. However, there was a large variability in this data (1.0% standard deviation and 3.0% range in data) which would indicate that the sole use of volumetrics to achieve performance will result in mixture performance variability (i.e. – some mixtures will meet performance while other mixtures will not meet performance).

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APPENDIX A – BALANCED MIXTURE DESIGN DETAILED RESULTS

Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

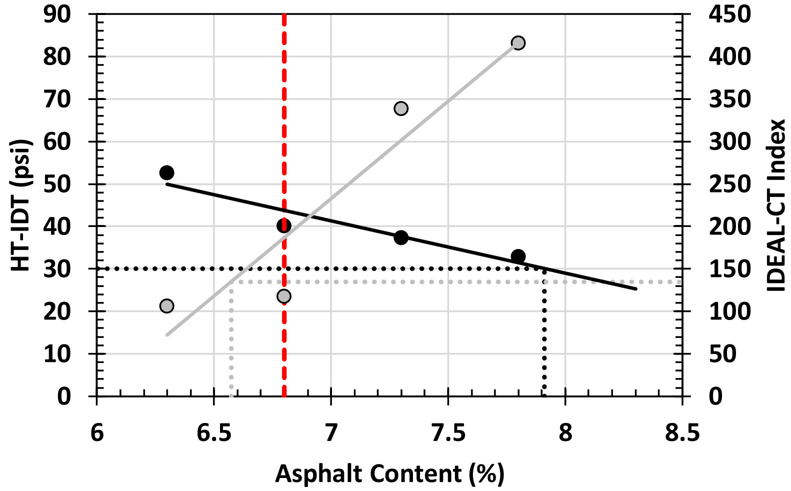
Region: 1
Supplier: New Castle

Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test:	HT-IDT	**Criteria:** >	30 psi
Fatigue Cracking Test:	IDEAL-CT	**Criteria:** >	135

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	**6.57**
Maximum Asphalt Content (%):	**7.91**
Volumetric Asphalt Content (%):	**6.8**

BALANCED

RAPL is accredited by AASHTO's AMRL Program

AASHTO Designation: M XXX-XX

AASHTO

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

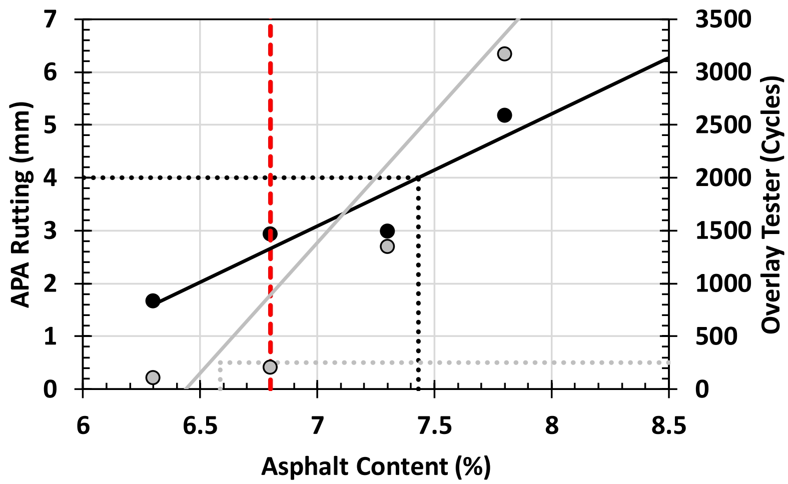
Region: 1
Supplier: New Castle

Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test: APA — **Criteria:** < 4 mm
Fatigue Cracking Test: Overlay Tester — **Criteria:** > 250 cycles

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	**6.59**
Maximum Asphalt Content (%):	**7.43**
Volumetric Asphalt Content (%):	**6.8**

BALANCED

AASHTO R18

RAPL is accredited by AASHTO's AMRL Program

Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

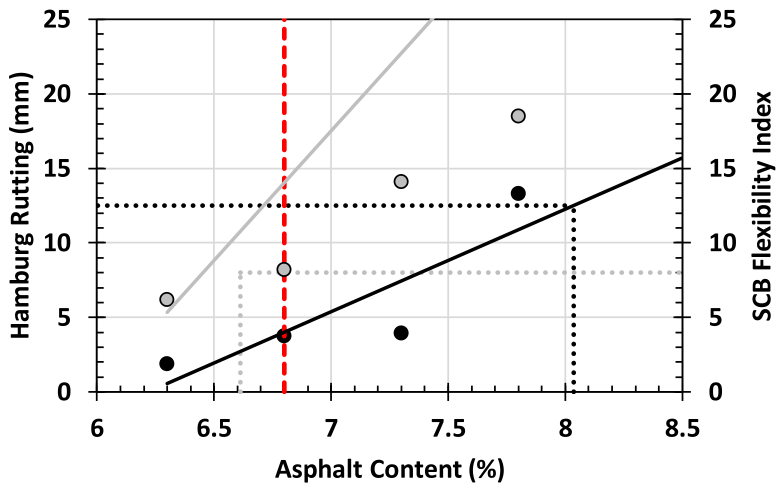
Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

Region: 1
Supplier: New Castle
Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test:	Hamburg Wheel Tracking	**Criteria:** <	12.5 mm
Fatigue Cracking Test:	SCB Flexibility Index	**Criteria:** >	8

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	**6.61**	**BALANCED**
Maximum Asphalt Content (%):	**8.04**	
Volumetric Asphalt Content (%):	**6.8**	

AASHTO R18

RAPL is accredited by AASHTO's AMRL Program

Standard Specification for

Balanced Mix Design

AASHTO Designation: M XXX-XX

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

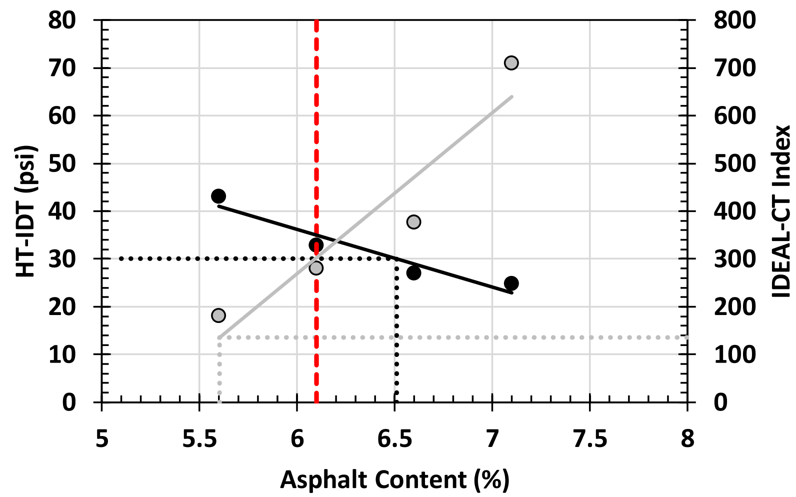
Region: 2
Supplier: Callanan

Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test: HT-IDT — **Criteria:** > 30 psi
Fatigue Cracking Test: IDEAL-CT — **Criteria:** > 135

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%): **5.60**
Maximum Asphalt Content (%): **6.51**
Volumetric Asphalt Content (%): **6.1**

BALANCED

AASHTO R18

RAPL is accredited by AASHTO's AMRL Program

Standard Specification for

Balanced Mix Design

AASHTO Designation: M XXX-XX

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

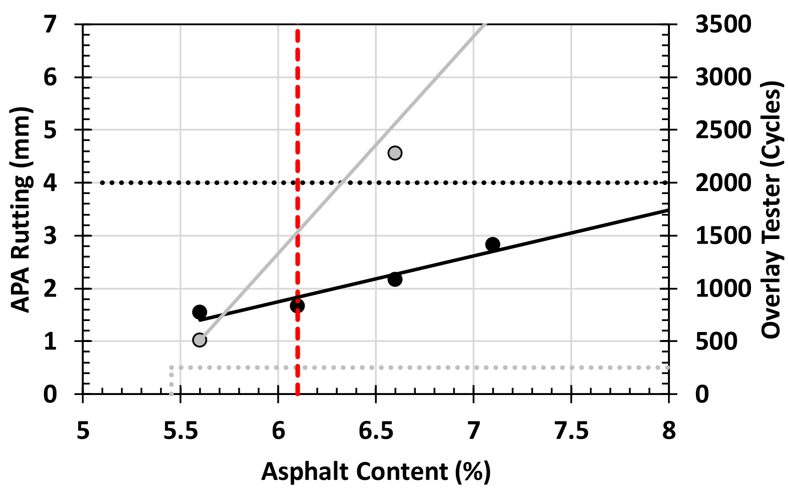
Region: 2
Supplier: Callanan

Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test:	APA	**Criteria:** <	4 mm
Fatigue Cracking Test:	Overlay Tester	**Criteria:** >	250 cycles

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	**5.45**	**BALANCED**
Maximum Asphalt Content (%):	**8.60**	
Volumetric Asphalt Content (%):	**6.1**	

AASHTO R18

RAPL is accredited by AASHTO's AMRL Program

Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

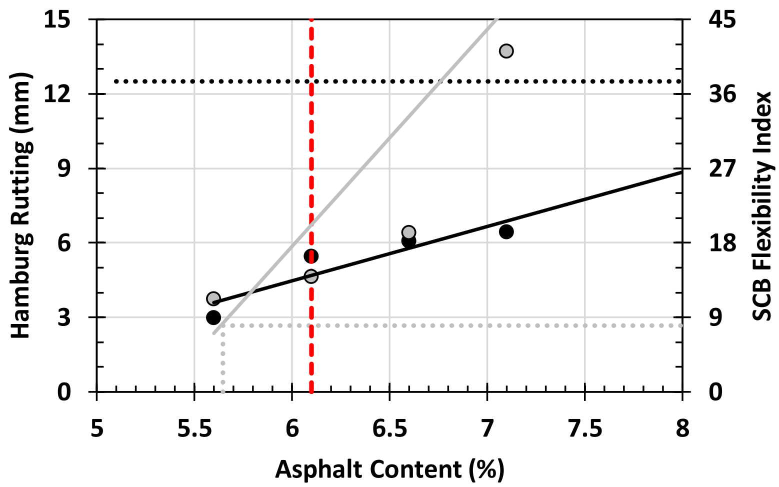
Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

Region: 2
Supplier: Callanan
Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test: Hamburg Wheel Tracking **Criteria:** < 12.5 mm
Fatigue Cracking Test: SCB Flexibility Index **Criteria:** > 8

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	**5.65**
Maximum Asphalt Content (%):	**9.67**
Volumetric Asphalt Content (%):	**6.1**

BALANCED

AASHTO R18

RAPL is accredited by AASHTO's AMRL Program

AASHTO Designation: M XXX-XX

AASHTO

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

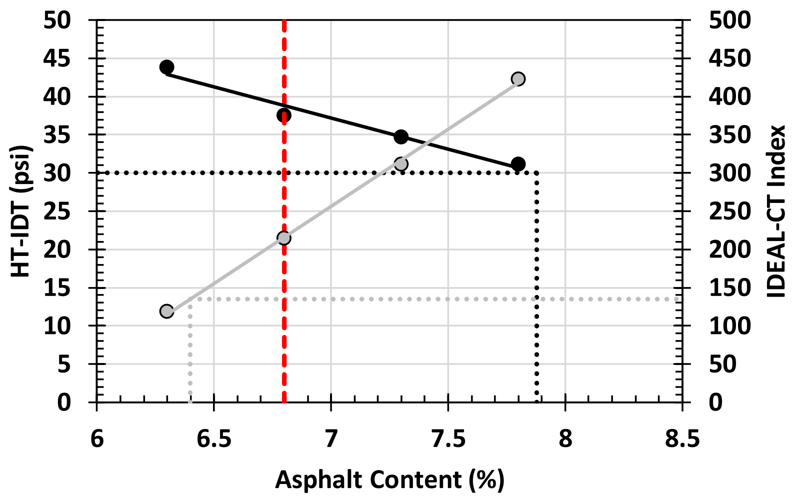
Region: 3
Supplier: Hanson

Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test: HT-IDT — **Criteria:** > 30 psi
Fatigue Cracking Test: IDEAL-CT — **Criteria:** > 135

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%): **6.40**
Maximum Asphalt Content (%): **7.88**
Volumetric Asphalt Content (%): **6.8**

BALANCED

AASHTO R18

RAPL is accredited by AASHTO's AMRL Program

AASHTO Designation: M XXX-XX

AASHTO

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

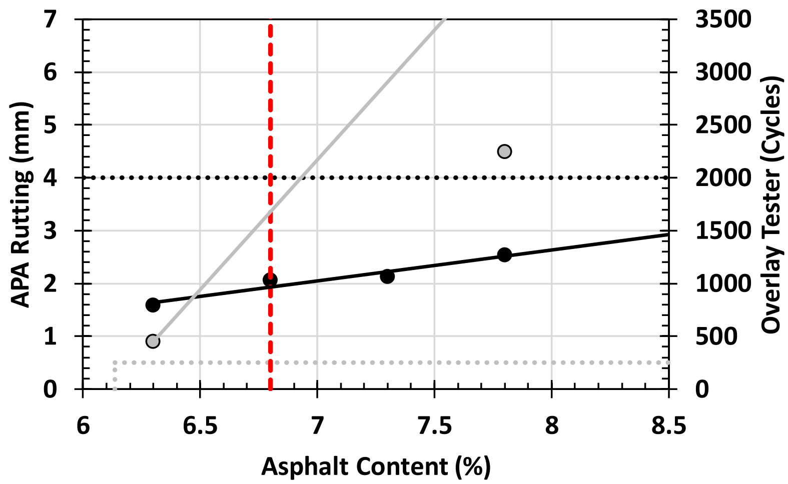
Region: 3
Supplier: Hanson

Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test:	APA	**Criteria:** <	4 mm
Fatigue Cracking Test:	Overlay Tester	**Criteria:** >	250 cycles

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	6.13
Maximum Asphalt Content (%):	10.34
Volumetric Asphalt Content (%):	6.8

BALANCED

AASHTO R18

RAPL is accredited by AASHTO's AMRL Program

Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

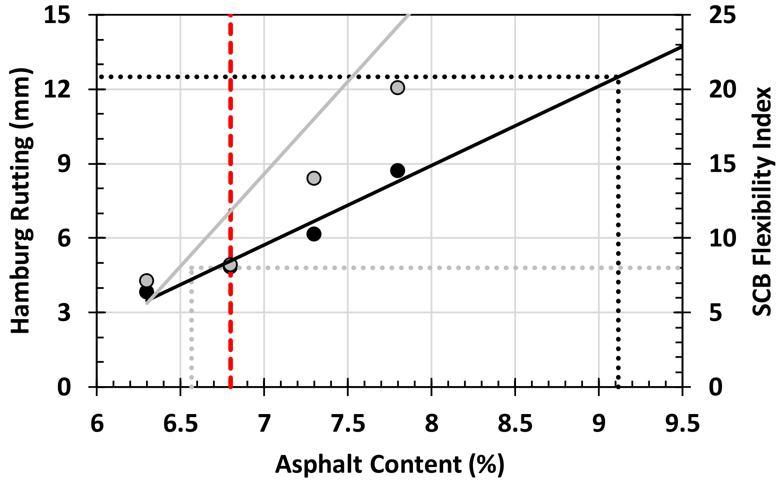
Region: 3
Supplier: Hanson

Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test:	Hamburg Wheel Tracking	**Criteria:** <	12.5 mm
Fatigue Cracking Test:	SCB Flexibility Index	**Criteria:** >	8

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	6.56
Maximum Asphalt Content (%):	9.12
Volumetric Asphalt Content (%):	6.8

BALANCED

AASHTO R18

RAPL is accredited by AASHTO's AMRL Program

AASHTO Designation: M XXX-XX

AASHTO

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

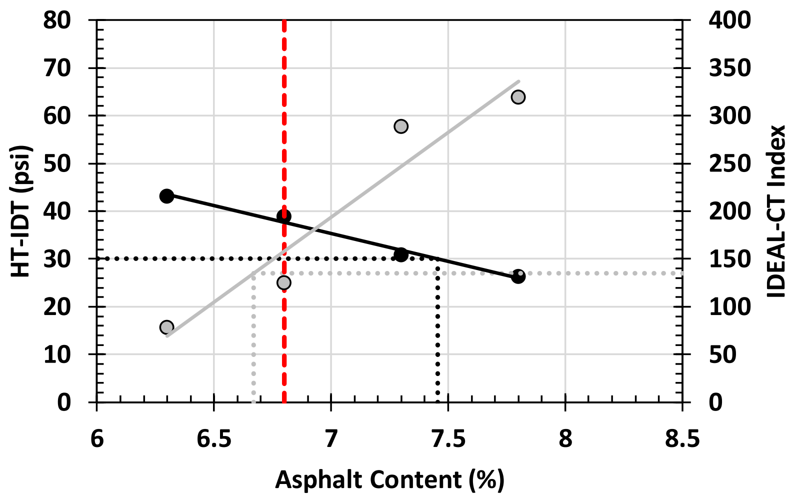
Region: Region 3
Supplier: Suit Kote Polkville

Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test:	HT-IDT	**Criteria:** >	30 psi
Fatigue Cracking Test:	IDEAL-CT	**Criteria:** >	135

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	**6.67**
Maximum Asphalt Content (%):	**7.46**
Volumetric Asphalt Content (%):	**6.8**

BALANCED

AASHTO R18

RAPL is accredited by AASHTO's AMRL Program

AASHTO Designation: M XXX-XX

AASHTO

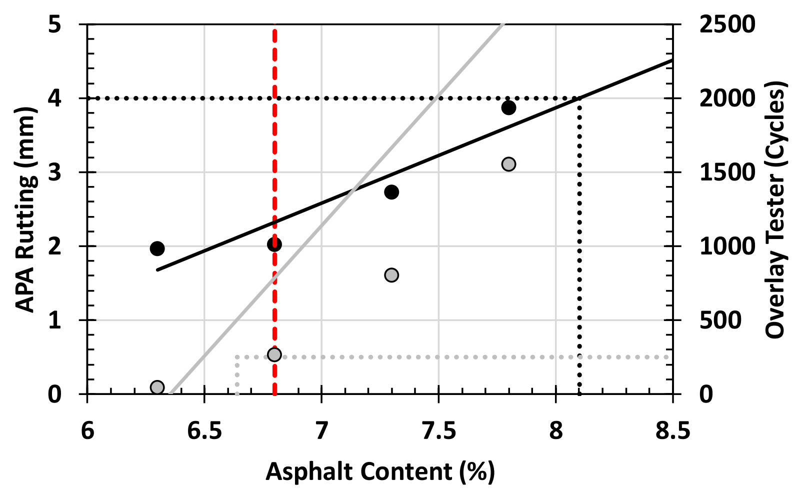
Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

Region: Region 3
Supplier: Suit Kote Polkville
Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test: APA — **Criteria:** < 4 mm
Fatigue Cracking Test: Overlay Tester — **Criteria:** > 250 cycles

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	**6.64**
Maximum Asphalt Content (%):	**8.10**
Volumetric Asphalt Content (%):	**6.8**

BALANCED

AASHTO R18
RAPL is accredited by AASHTO's AMRL Program

AASHTO Designation: M XXX-XX

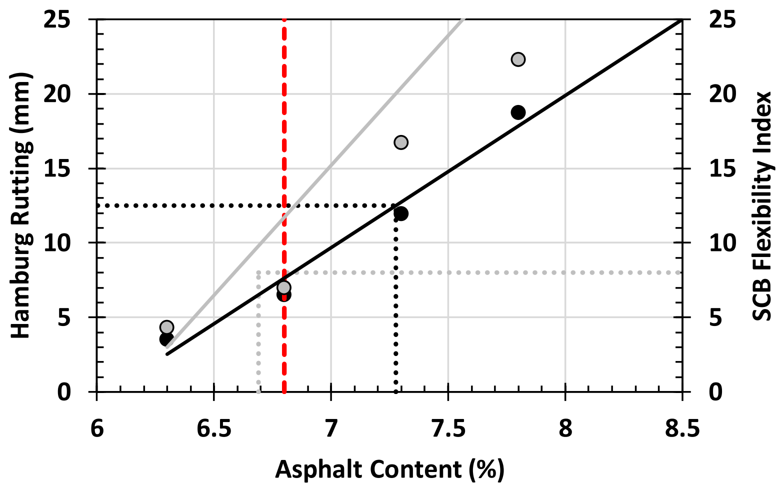
Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

Region: Region 3 **Design Traffic Level:** > 0.3
Supplier: Suit Kote Polkville **Asphalt Binder Grade:** PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test:	Hamburg Wheel Tracking	**Criteria:** <	12.5 mm
Fatigue Cracking Test:	SCB Flexibility Index	**Criteria:** >	8

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	6.69
Maximum Asphalt Content (%):	7.28
Volumetric Asphalt Content (%):	6.8

BALANCED

RAPL is accredited by AASHTO's AMRL Program

Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

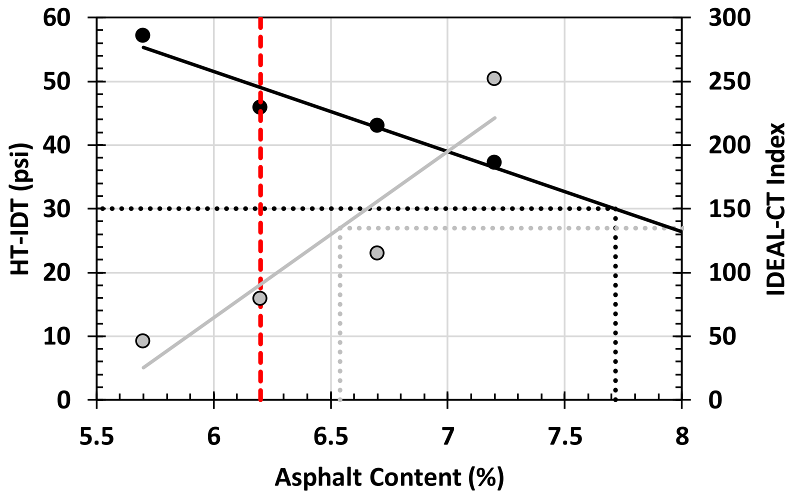
Region: 4
Supplier: Barre-Stone

Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test: HT-IDT — **Criteria:** > 30 psi
Fatigue Cracking Test: IDEAL-CT — **Criteria:** > 135

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%): **6.54**
Maximum Asphalt Content (%): **7.72**
Volumetric Asphalt Content (%): **6.2**

NOT BALANCED

AASHTO R18

RAPL is accredited by AASHTO's AMRL Program

Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

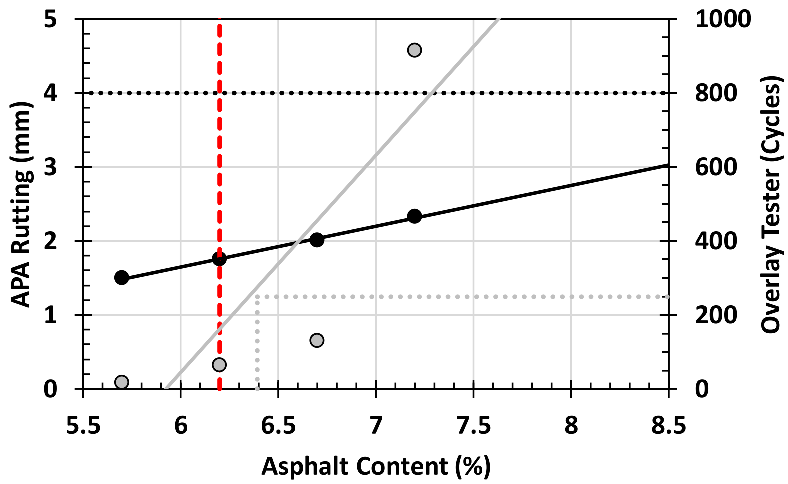
Region: 4
Supplier: Barre-Stone

Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test: APA — **Criteria:** < 4 mm
Fatigue Cracking Test: Overlay Tester — **Criteria:** > 250 cycles

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	**6.39**
Maximum Asphalt Content (%):	**10.27**
Volumetric Asphalt Content (%):	**6.2**

NOT BALANCED

AASHTO R18

RAPL is accredited by AASHTO's AMRL Program

Standard Specification for

Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

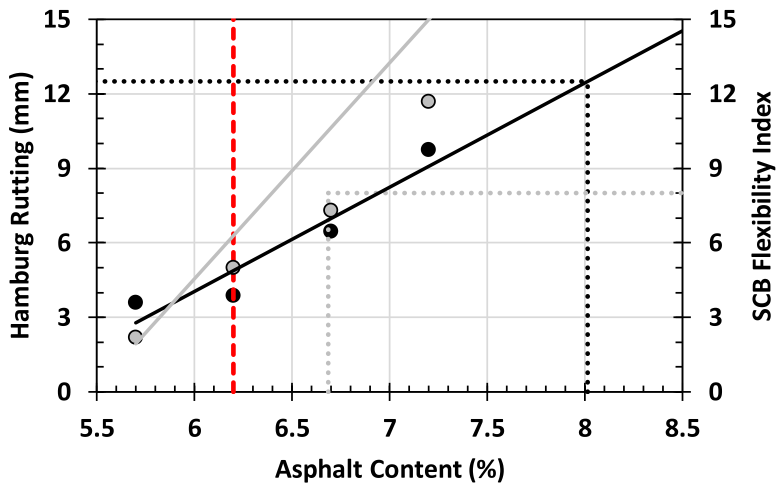
Region: 4
Supplier: Barre-Stone

Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test:	Hamburg Wheel Tracking	**Criteria:** <	12.5 mm
Fatigue Cracking Test:	SCB Flexibility Index	**Criteria:** >	8

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	**6.69**
Maximum Asphalt Content (%):	**8.02**
Volumetric Asphalt Content (%):	**6.2**

NOT BALANCED

AASHTO R18

RAPL is accredited by AASHTO's AMRL Program

AASHTO Designation: M XXX-XX

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

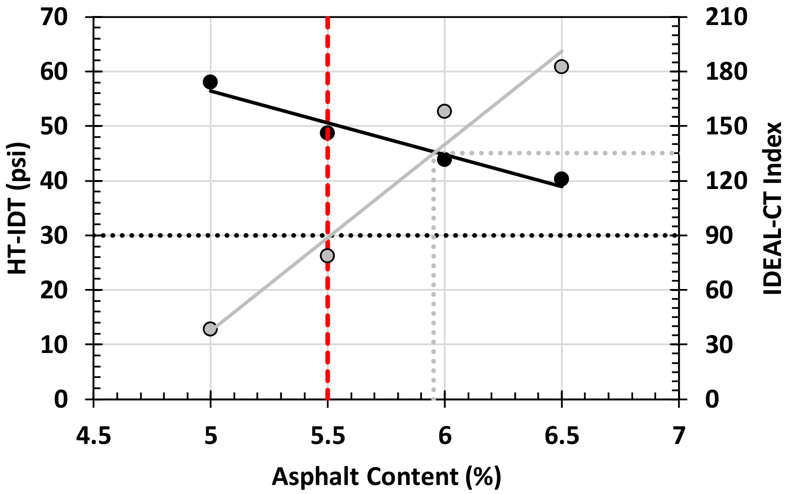
Region: 4
Supplier: Hanson

Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test: HT-IDT — **Criteria:** > 30 psi
Fatigue Cracking Test: IDEAL-CT — **Criteria:** > 135

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%): **5.95**
Maximum Asphalt Content (%): **7.27**
Volumetric Asphalt Content (%): **5.5**

NOT BALANCED

RAPL is accredited by AASHTO's AMRL Program

Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

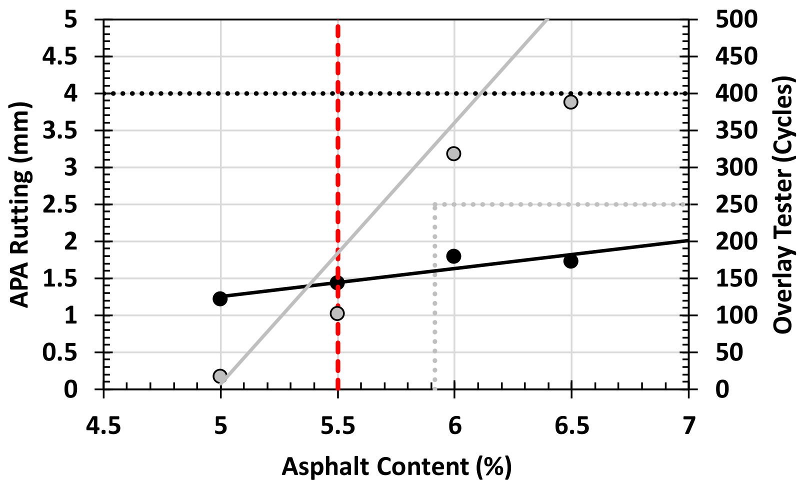
Region: 4
Supplier: Hanson

Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test:	APA	**Criteria:** <	4 mm
Fatigue Cracking Test:	Overlay Tester	**Criteria:** >	250 cycles

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	**5.92**
Maximum Asphalt Content (%):	**12.26**
Volumetric Asphalt Content (%):	**5.5**

NOT BALANCED

AASHTO R18

RAPL is accredited by AASHTO's AMRL Program

AASHTO Designation: M XXX-XX

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

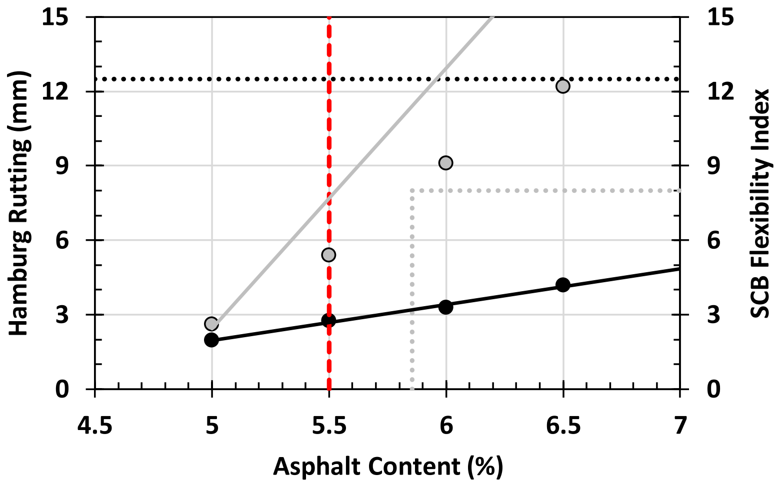
Region: 4
Supplier: Hanson

Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test:	Hamburg Wheel Tracking	**Criteria:** <	12.5 mm
Fatigue Cracking Test:	SCB Flexibility Index	**Criteria:** >	8

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	5.85
Maximum Asphalt Content (%):	12.29
Volumetric Asphalt Content (%):	5.5

NOT BALANCED

AASHTO R18

RAPL is accredited by AASHTO's AMRL Program

Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

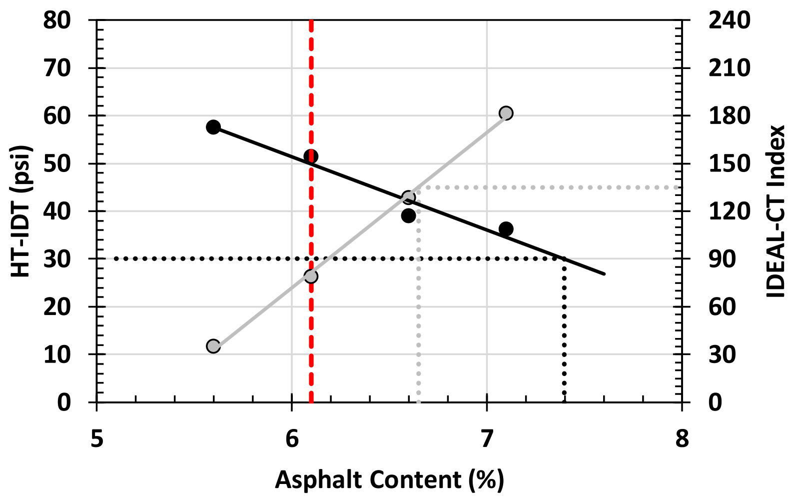
Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

Region: 5
Supplier: County Line
Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test:	HT-IDT	**Criteria:** >	30 psi
Fatigue Cracking Test:	IDEAL-CT	**Criteria:** >	135

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%): **6.65**
Maximum Asphalt Content (%): **7.40**
Volumetric Asphalt Content (%): **6.1**

NOT BALANCED

AASHTO R18
RAPL is accredited by AASHTO's AMRL Program

Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

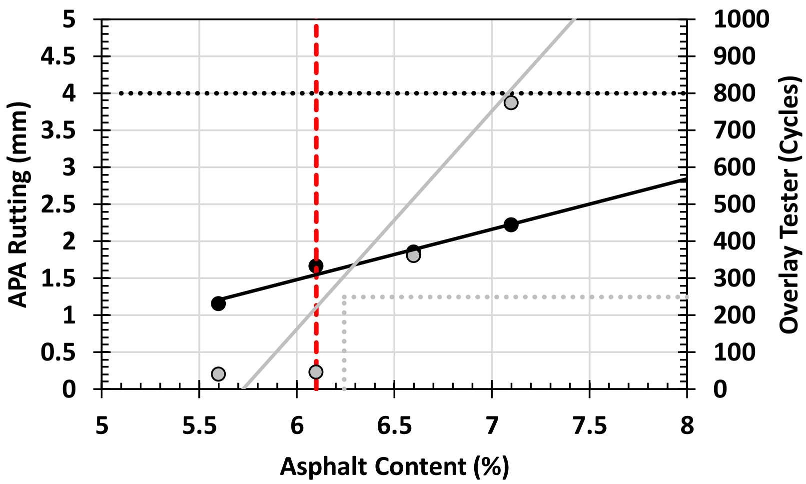
Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

Region: 5
Supplier: County Line
Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test: APA — **Criteria:** < 4 mm
Fatigue Cracking Test: Overlay Tester — **Criteria:** > 250 cycles

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	6.24
Maximum Asphalt Content (%):	9.70
Volumetric Asphalt Content (%):	6.1

NOT BALANCED

AASHTO R18

RAPL is accredited by AASHTO's AMRL Program

Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

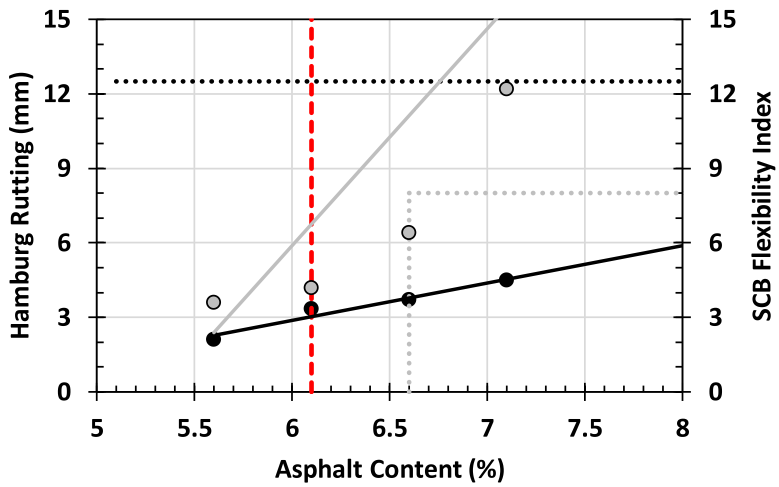
Region: 5
Supplier: County Line

Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test:	Hamburg Wheel Tracking	**Criteria:** <	12.5 mm
Fatigue Cracking Test:	SCB Flexibility Index	**Criteria:** >	8

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	**6.60**
Maximum Asphalt Content (%):	**12.39**
Volumetric Asphalt Content (%):	**6.1**

NOT BALANCED

AASHTO R18

RAPL is accredited by AASHTO's AMRL Program

AASHTO Designation: M XXX-XX

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

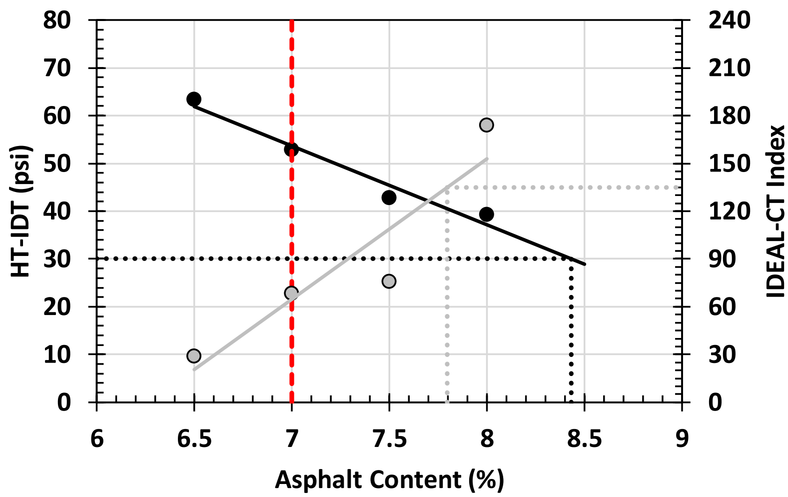
Region: 5
Supplier: Jamestown

Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test: HT-IDT — **Criteria:** > 30 psi
Fatigue Cracking Test: IDEAL-CT — **Criteria:** > 135

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%): **7.80**
Maximum Asphalt Content (%): **8.43**
Volumetric Asphalt Content (%): **7.00**

NOT BALANCED

AASHTO R18

RAPL is accredited by AASHTO's AMRL Program

Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

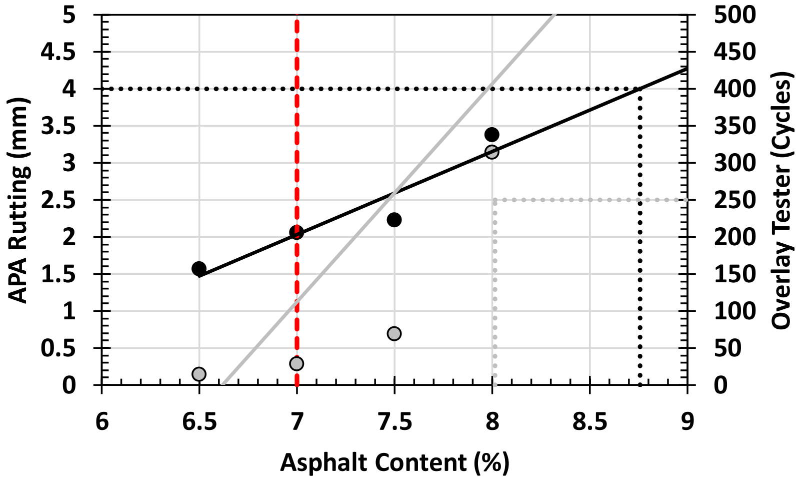
Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

Region: 5 **Design Traffic Level:** > 0.3
Supplier: Jamestown **Asphalt Binder Grade:** PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test:	APA	**Criteria:** <	4 mm
Fatigue Cracking Test:	Overlay Tester	**Criteria:** >	250 cycles

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	**8.01**	**NOT BALANCED**
Maximum Asphalt Content (%):	**8.76**	
Volumetric Asphalt Content (%):	**7.00**	

AASHTO R18

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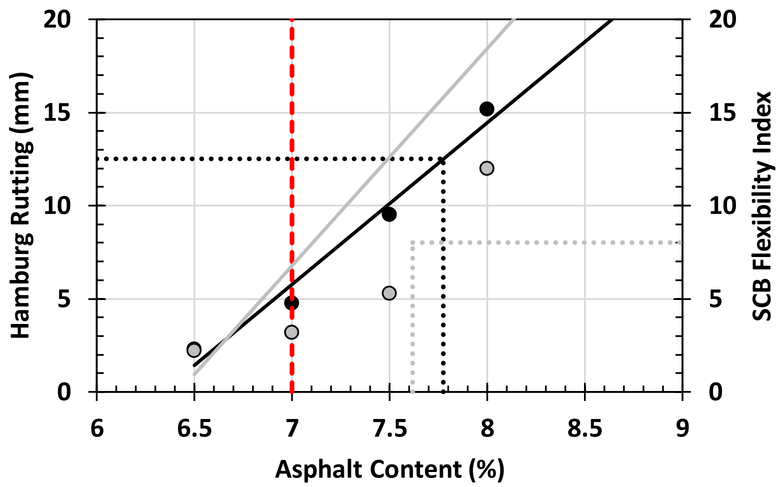
Region: 5 **Design Traffic Level:** > 0.3

Supplier: Jamestown **Asphalt Binder Grade:** PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test:	Hamburg Wheel Tracking	**Criteria:**	<	12.5 mm
Fatigue Cracking Test:	SCB Flexibility Index	**Criteria:**	>	8

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	**7.62**
Maximum Asphalt Content (%):	**7.78**
Volumetric Asphalt Content (%):	**7.00**

NOT BALANCED

Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

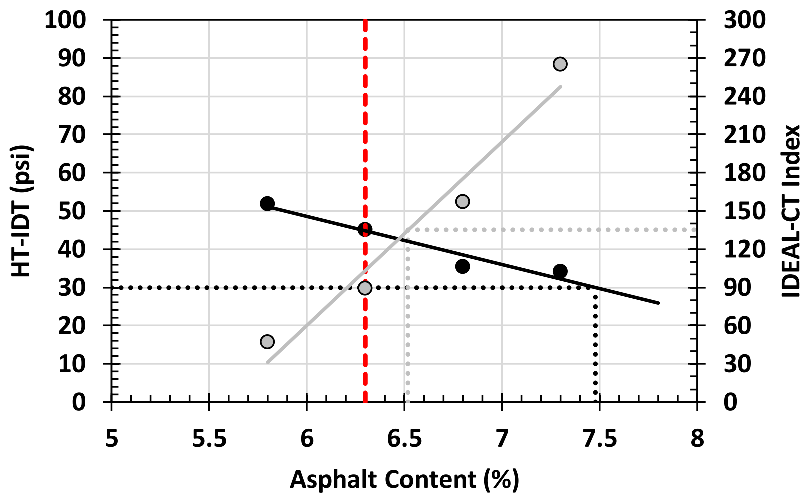
Region: 6
Supplier: Blades Hornell

Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test:	HT-IDT	**Criteria:** >	30 psi
Fatigue Cracking Test:	IDEAL-CT	**Criteria:** >	135

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	**6.52**	**NOT BALANCED**
Maximum Asphalt Content (%):	**7.48**	
Volumetric Asphalt Content (%):	**6.3**	

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Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

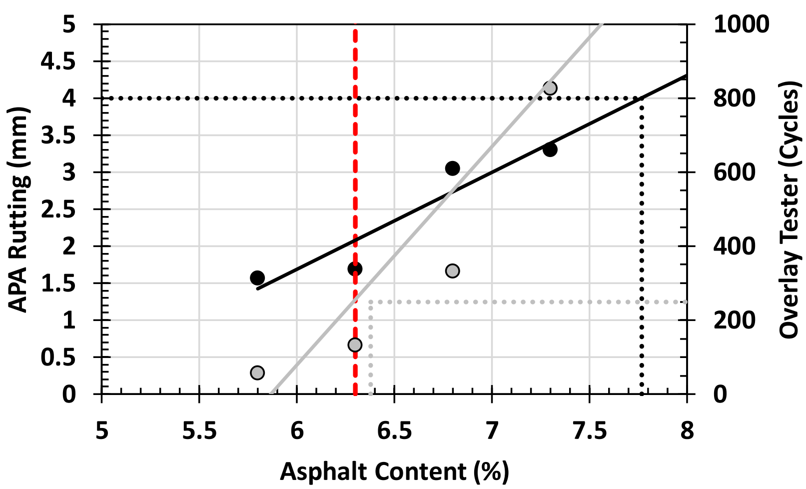
Region: 6
Supplier: Blades Hornell

Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test:	APA	**Criteria:** <	4 mm
Fatigue Cracking Test:	Overlay Tester	**Criteria:** >	250 cycles

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	**6.38**	**NOT BALANCED**
Maximum Asphalt Content (%):	**7.77**	
Volumetric Asphalt Content (%):	**6.3**	

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Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

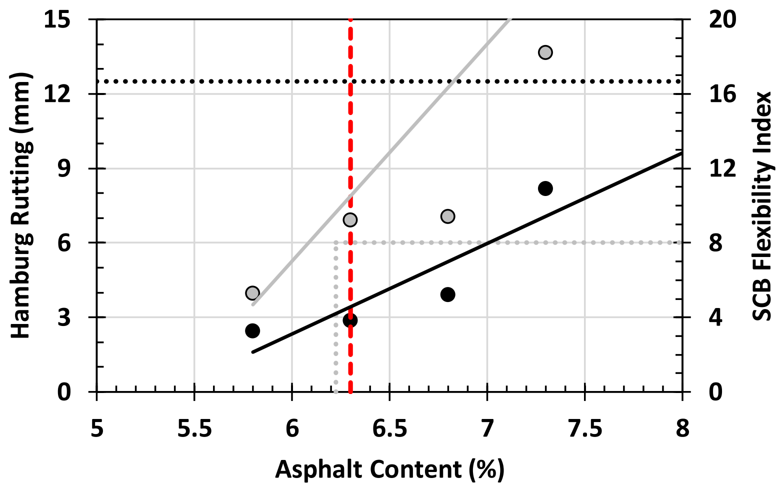
Region: 6
Supplier: Blades Hornell

Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test:	Hamburg Wheel Tracking	**Criteria:** <	12.5 mm
Fatigue Cracking Test:	SCB Flexibility Index	**Criteria:** >	8

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	6.23
Maximum Asphalt Content (%):	8.79
Volumetric Asphalt Content (%):	6.3

BALANCED

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Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

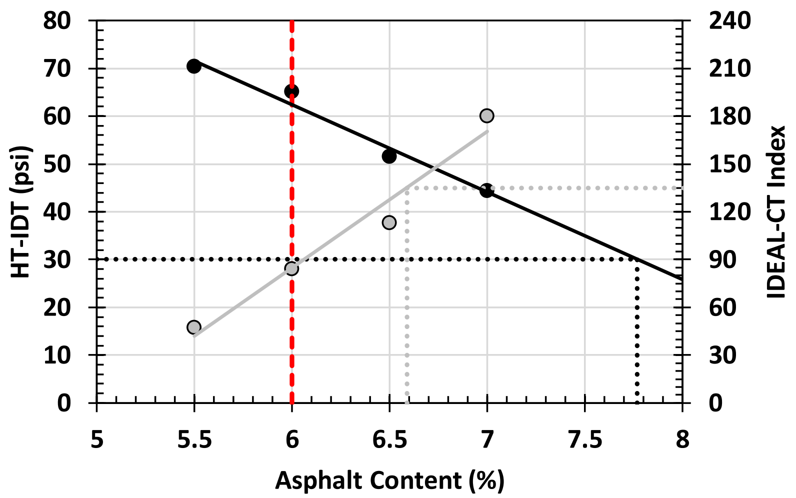
Region: 10
Supplier: Rason

Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64E-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test:	HT-IDT	**Criteria:** >	30 psi
Fatigue Cracking Test:	IDEAL-CT	**Criteria:** >	135

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	**6.59**	**NOT BALANCED**
Maximum Asphalt Content (%):	**7.77**	
Volumetric Asphalt Content (%):	**6.0**	

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Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

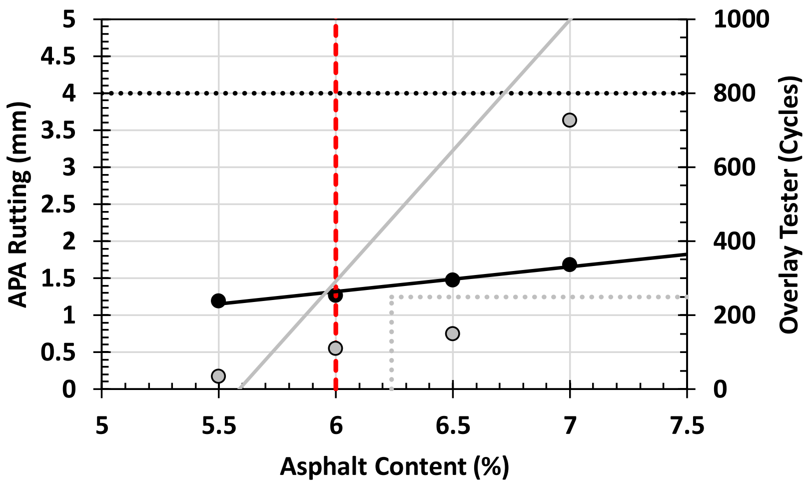
Region: 10
Supplier: Rason

Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64E-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test:	APA	**Criteria:** <	4 mm
Fatigue Cracking Test:	Overlay Tester	**Criteria:** >	250 cycles

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	**6.24**
Maximum Asphalt Content (%):	**13.99**
Volumetric Asphalt Content (%):	**6.0**

NOT BALANCED

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Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

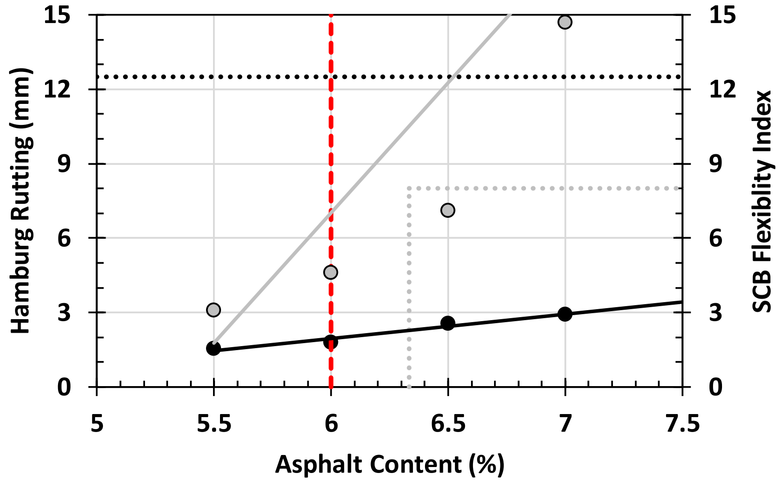
Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

Region: 10 **Design Traffic Level:** > 0.3
Supplier: Rason **Asphalt Binder Grade:** PG64E-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test:	Hamburg Wheel Tracking	**Criteria:** <	12.5 mm
Fatigue Cracking Test:	SCB Flexibility Index	**Criteria:** >	8

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	**6.33**
Maximum Asphalt Content (%):	**16.77**
Volumetric Asphalt Content (%):	**6.0**

NOT BALANCED

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Standard Specification for

Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

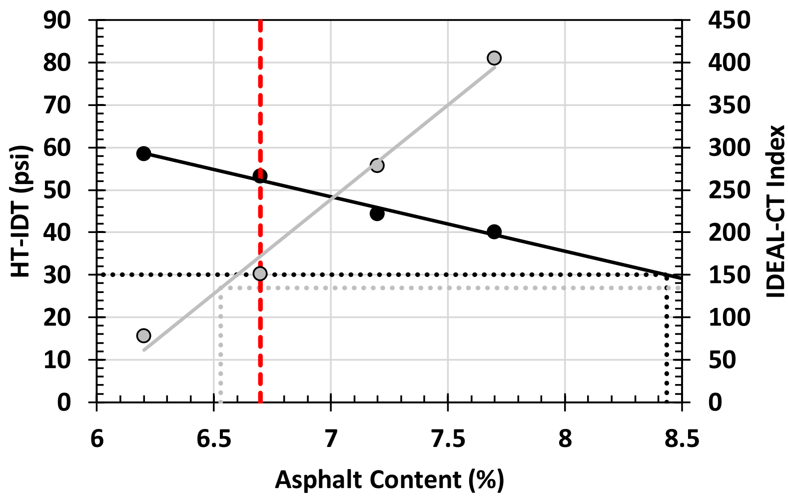
Region: 11
Supplier: Flushing

Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test: HT-IDT — **Criteria:** > 30 psi
Fatigue Cracking Test: IDEAL-CT — **Criteria:** > 135

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%): **6.53**
Maximum Asphalt Content (%): **8.43**
Volumetric Asphalt Content (%): **6.7**

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AASHTO R18

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Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

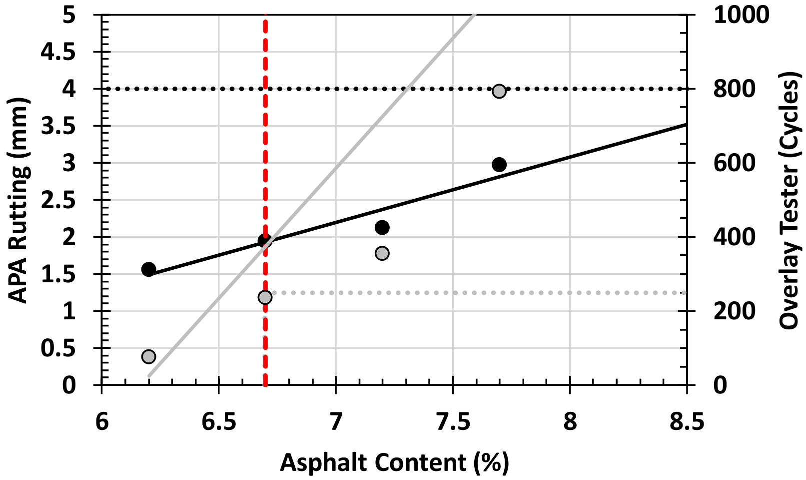
Region: 11
Supplier: Flushing

Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test: APA — **Criteria:** < 4 mm
Fatigue Cracking Test: Overlay Tester — **Criteria:** > 250 cycles

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	**6.70**
Maximum Asphalt Content (%):	**9.05**
Volumetric Asphalt Content (%):	**6.70**

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AASHTO R18

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Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

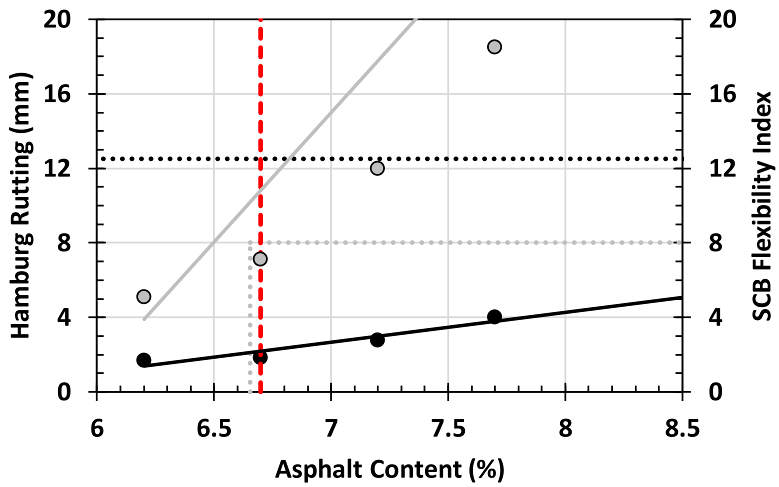
Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

Region: 11 | **Design Traffic Level:** > 0.3
Supplier: Flushing | **Asphalt Binder Grade:** PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test: Hamburg Wheel Tracking — **Criteria:** < 12.5 mm
Fatigue Cracking Test: SCB Flexibility Index — **Criteria:** > 8

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%):	**6.65**
Maximum Asphalt Content (%):	**13.14**
Volumetric Asphalt Content (%):	**6.7**

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APPENDIX B – NDESIGN AIR VOID BACKCALCULATION AT BMD ASPHALT CONTENTS

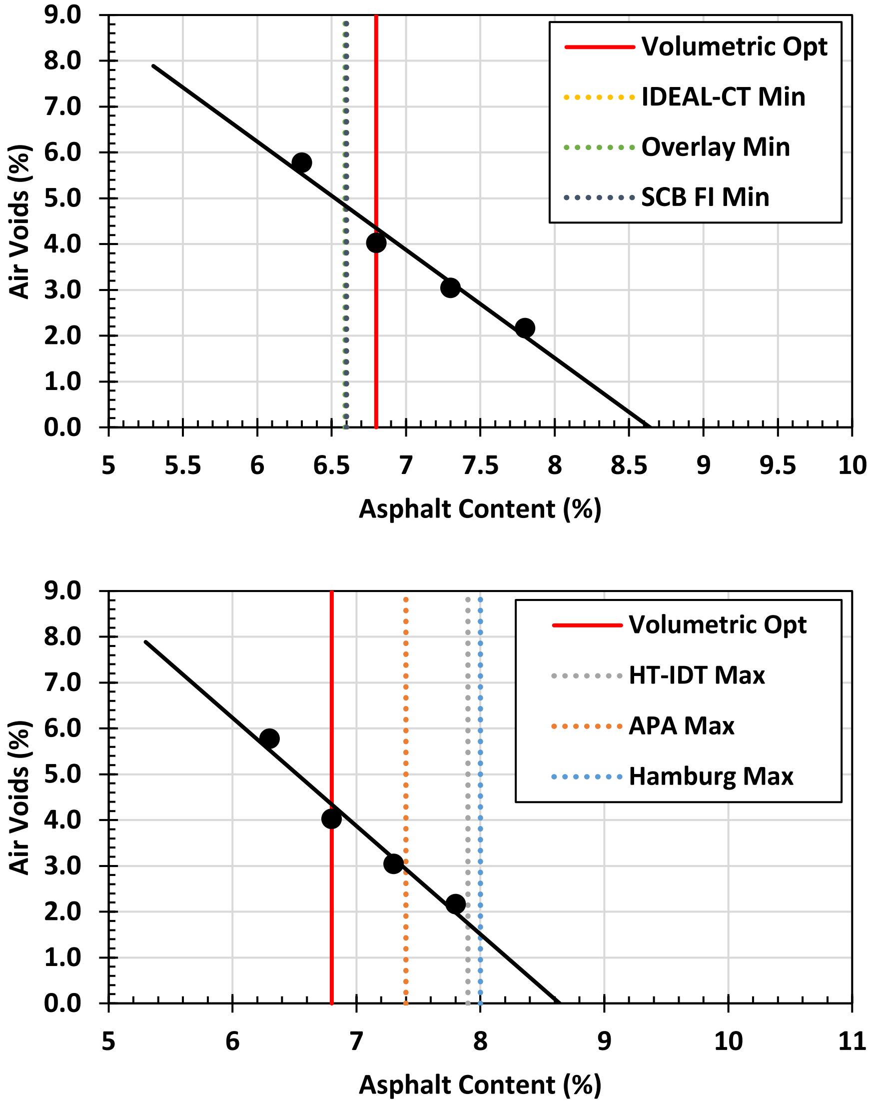
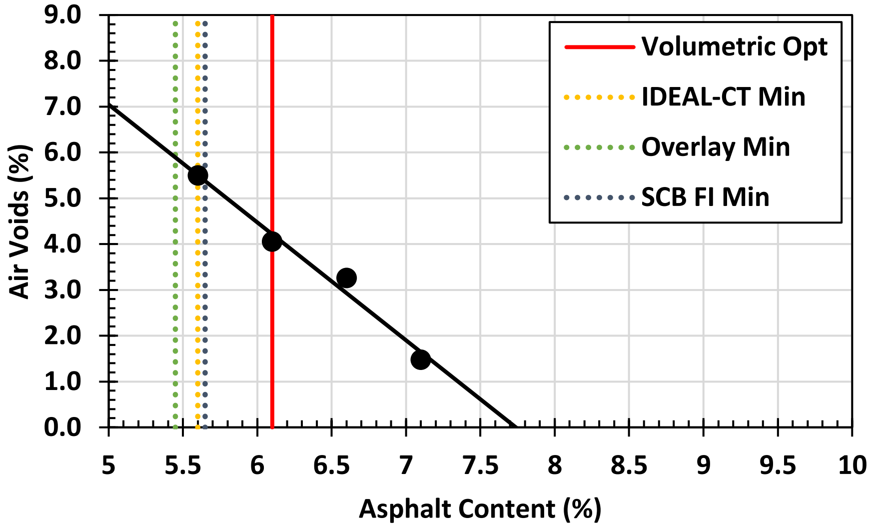


Figure B.1 – Region 1 N_{design} Air Void Backcalculation at BMD Asphalt Contents



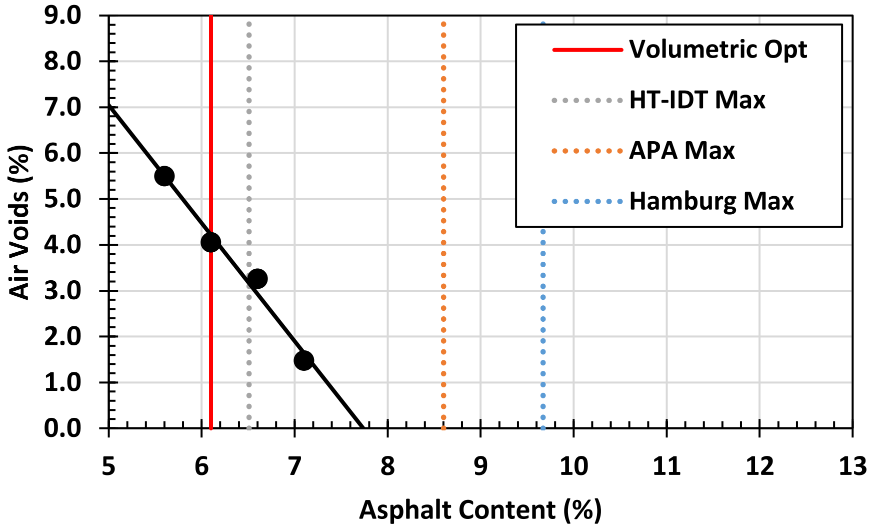


Figure B.2 – Region 2 N_{design} Air Void Backcalculation at BMD Asphalt Contents

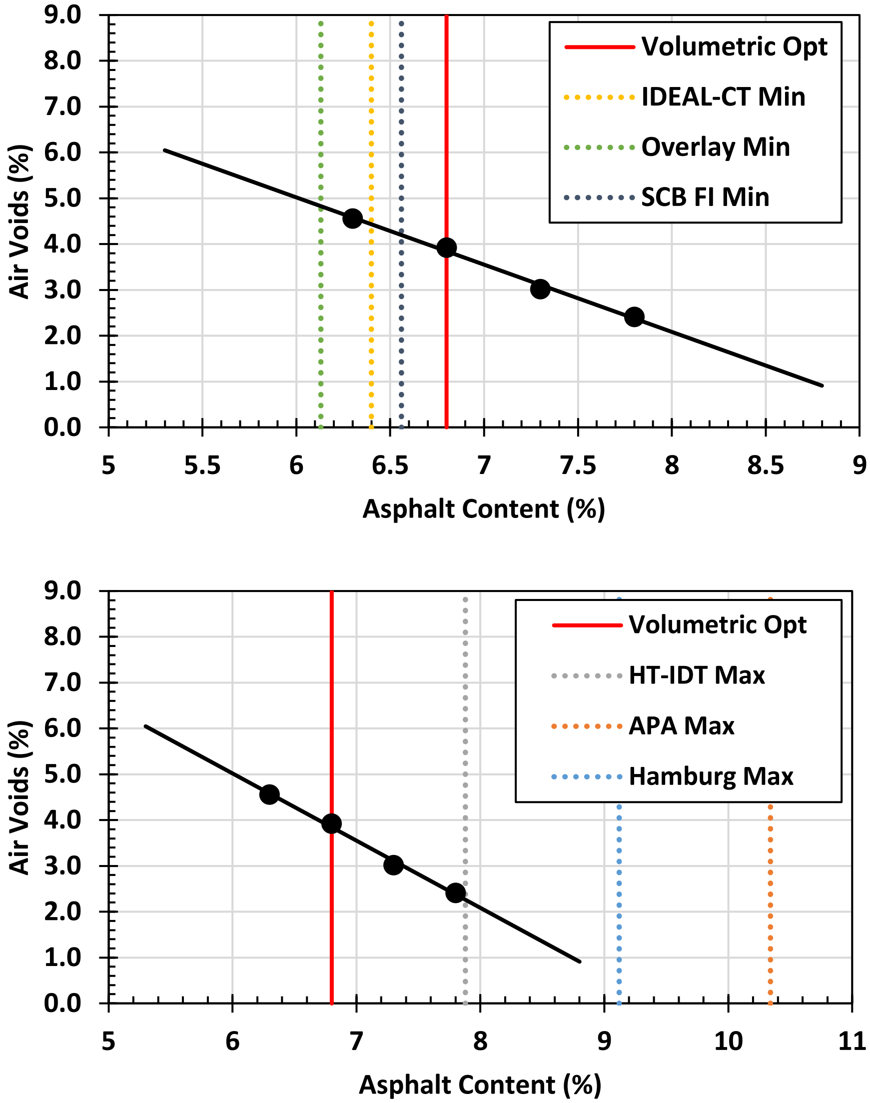


Figure B.3 – Region 3A N_{design} Air Void Backcalculation at BMD Asphalt Contents

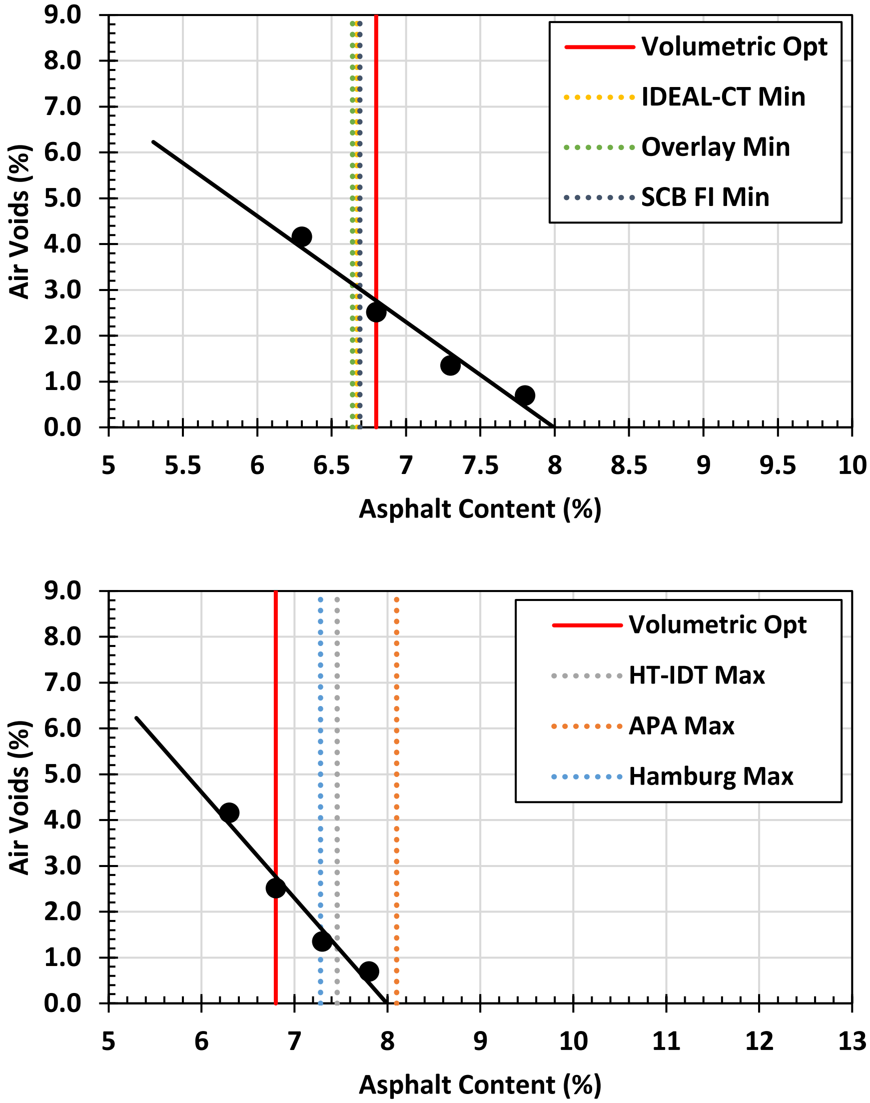
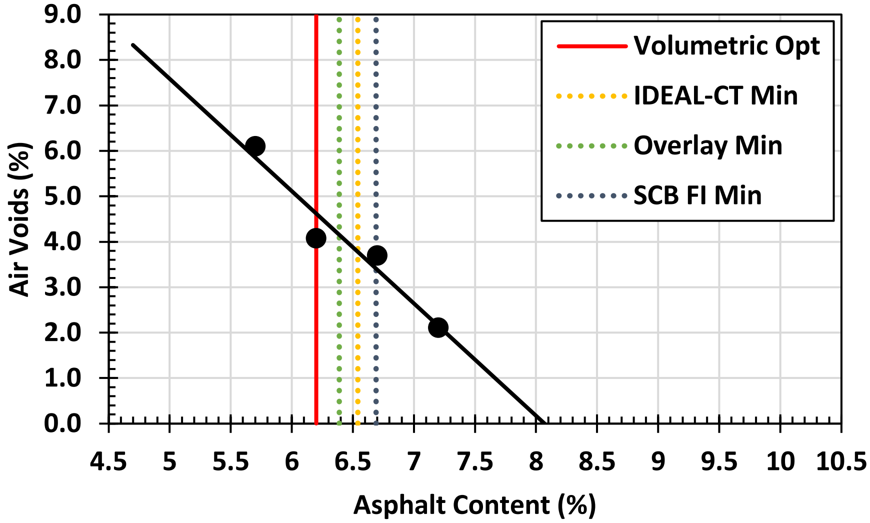


Figure B.4 – Region 3B N_{design} Air Void Backcalculation at BMD Asphalt Contents



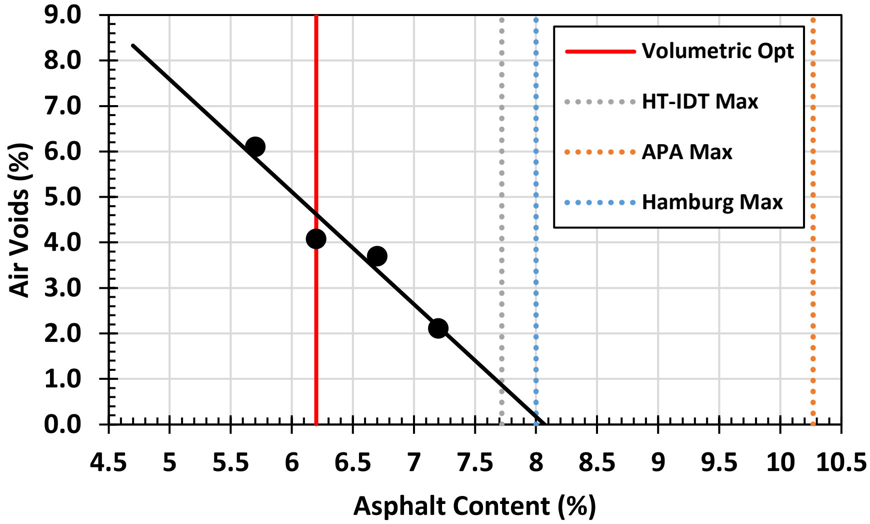
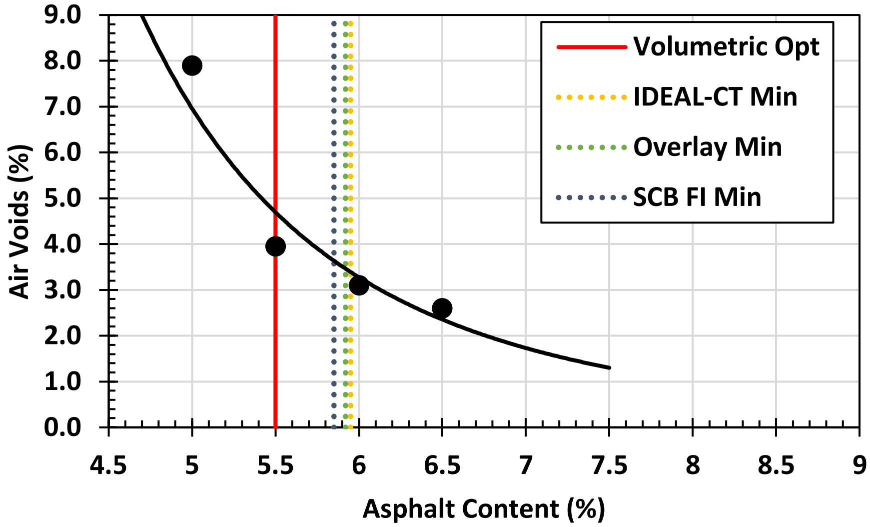


Figure B.5 – Region 4A N_{design} Air Void Backcalculation at BMD Asphalt Contents



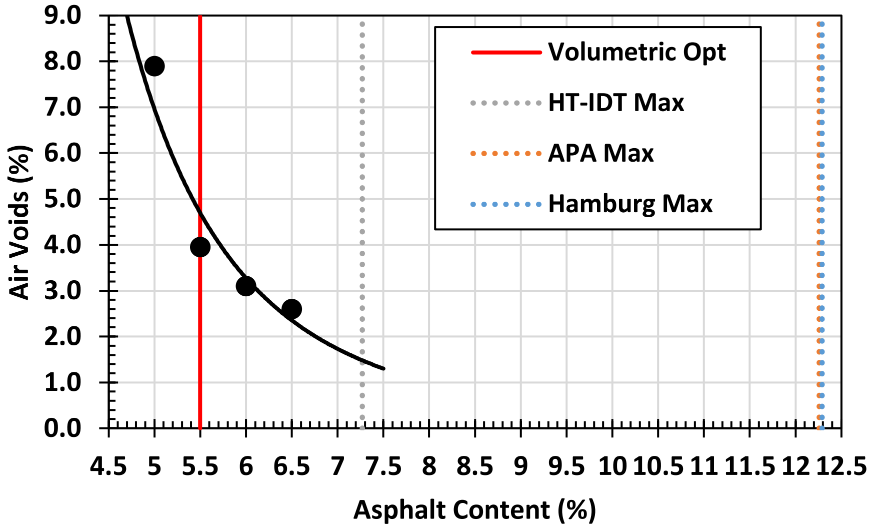


Figure B.6 – Region 4B N_{design} Air Void Backcalculation at BMD Asphalt Contents

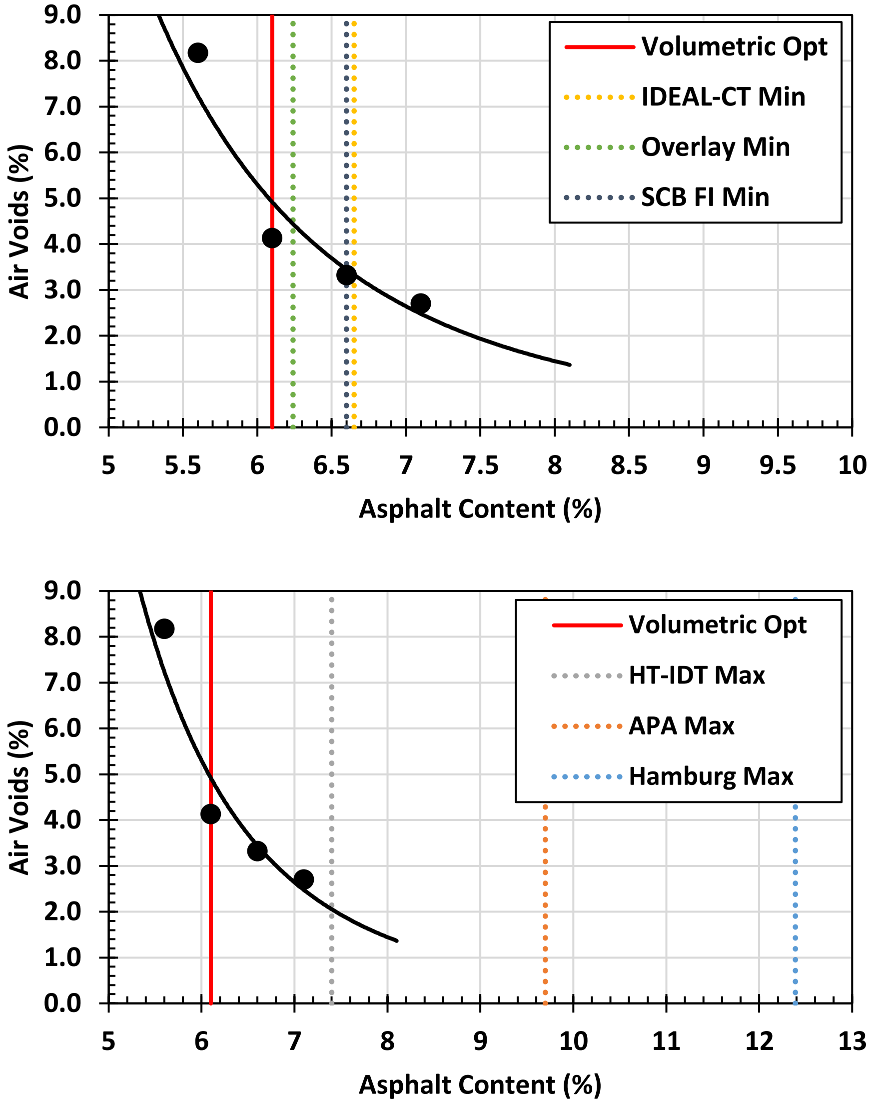


Figure B.7 – Region 5A N_{design} Air Void Backcalculation at BMD Asphalt Contents

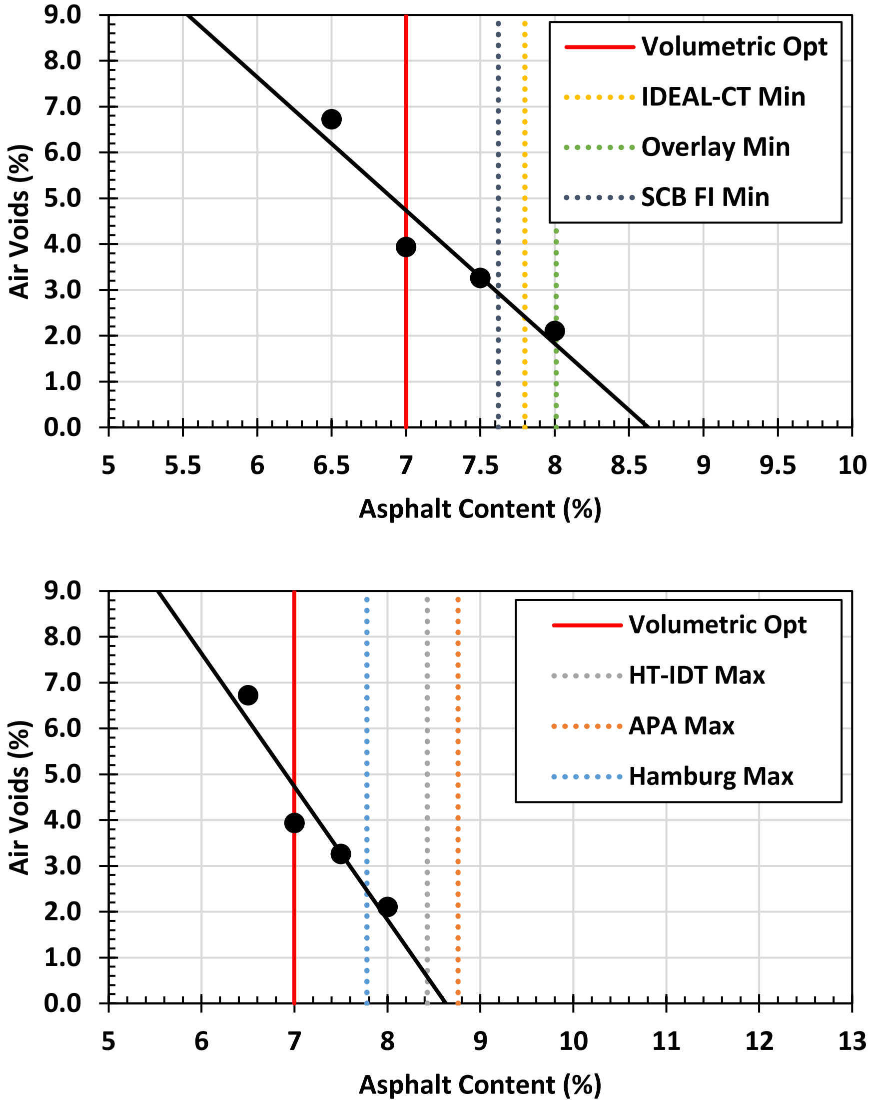
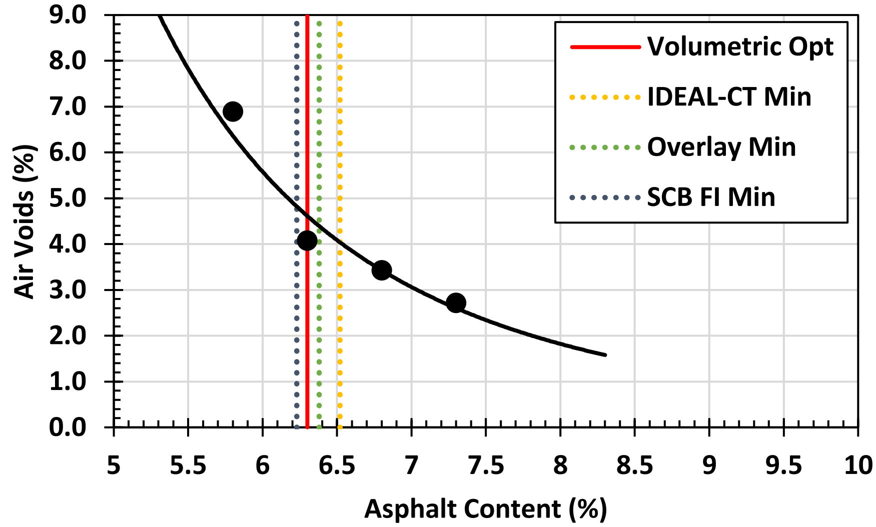


Figure B.8 – Region 5B N_{design} Air Void Backcalculation at BMD Asphalt Contents



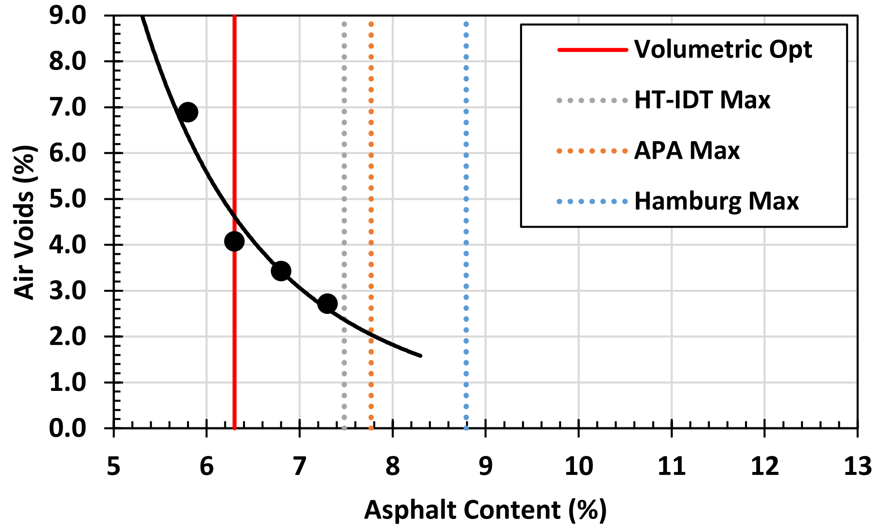
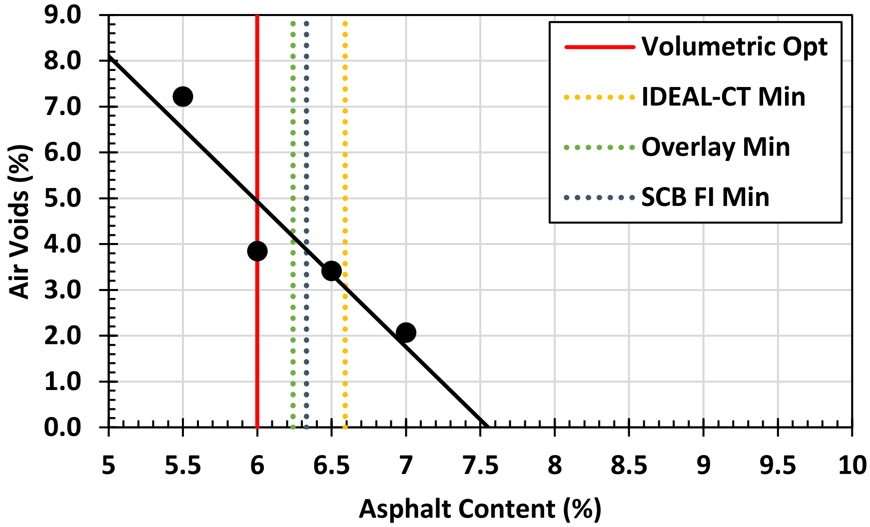


Figure B.9 – Region 6 N_{design} Air Void Backcalculation at BMD Asphalt Contents



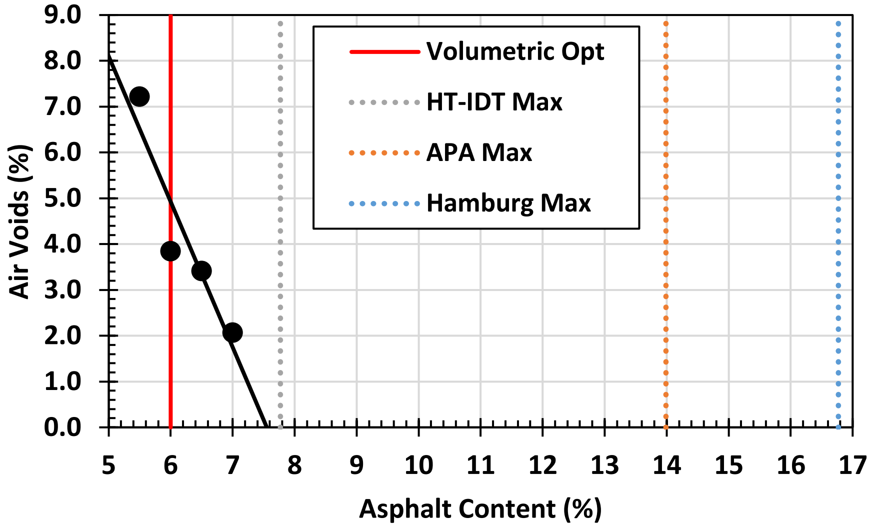


Figure B.10 – Region 10 N_{design} Air Void Backcalculation at BMD Asphalt Contents

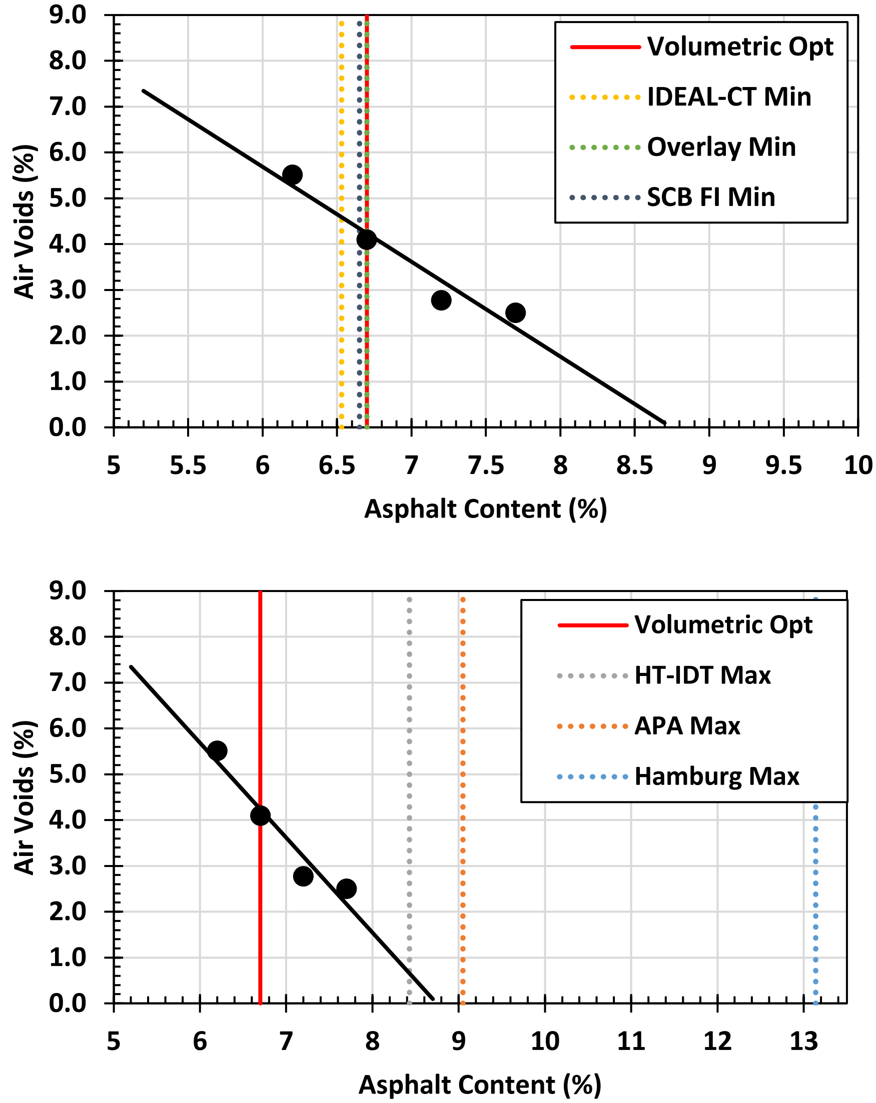


Figure B.11 – Region 11 N_{design} Air Void Backcalculation at BMD Asphalt Contents