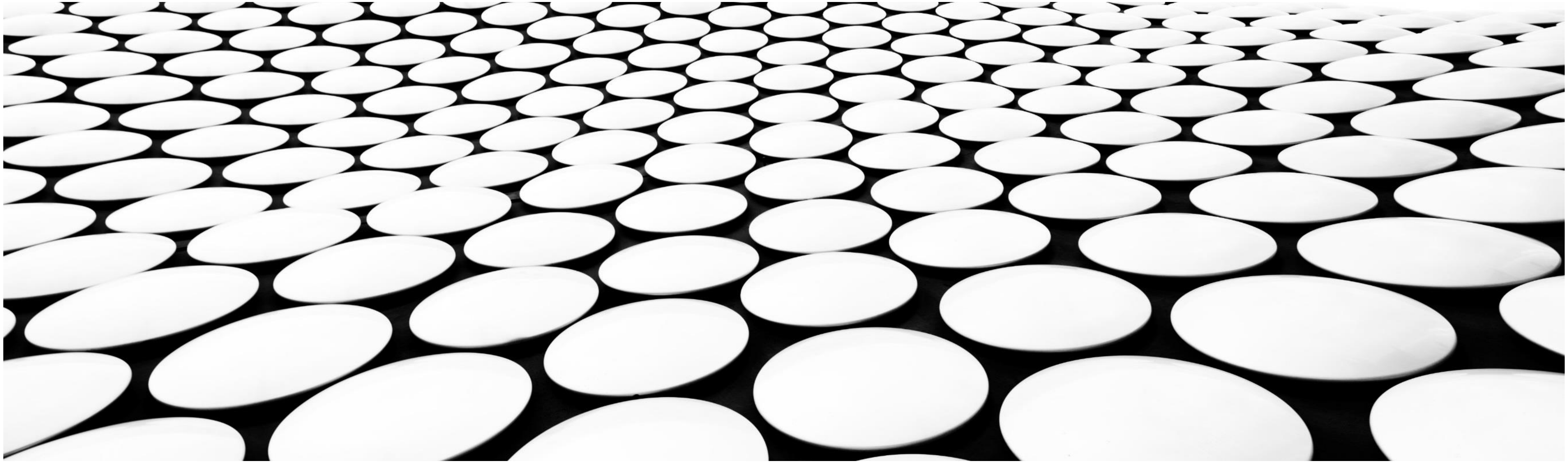
Performance Engineered Mixes

By Scott Quire, P.E.

Bluegrass Testing Laboratory



SCOTT QUIRE, P.E.
INSTRUCTOR

Scott is the Technical Director for Bluegrass Testing Laboratory. He is a registered engineer in Kentucky and Alaska.

Scott has over 36 years experience in the design, control, and placement of asphalt mixtures for racing courses, highways, commercial projects, and airport pavements across the United States and around the globe.

His experience also includes testing and oversite of construction materials (aggregate, asphalt mixtures, Portland cement concrete, asphalt binders) testing and training courses for construction materials testing.

Scott is an active Technical Committee Member for the Plantmix Asphalt Industry of Kentucky (PAIKY), Flexible Pavements of Ohio, Asphalt Pavement Association of Indiana (APAI), and the Missouri Asphalt Pavement Association (MAPA).

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Performance Engineered Mix OVER-VIEW

- **Why the need for Performance Engineered Mix Designs**
- **Define what a Performance Engineered Mix Design (PEMD) is**
- **Review of present AASHTO Draft Specification and Draft Practice**
- **Review of the four different approaches to Balanced Mix Design**
    - **Approaches A → D**
- **Review of FHWA allowing the use of Index-Based Performance Engineered Mix Designs (PEMD)**
- **Review of the index based tests for Balanced Mix Designs predominantly discussed and in use today**
- **Case Study**

Analysis Tools

Current Practice

Present System of Mix Analysis

- Aggregate properties determined (consensus properties, gradations, specific gravity, % absorption)
- Recycle analysis (% binder, gradation, aggregate properties)
- Initial aggregate structure is developed
- Trial binder content selected
- Specimens manufactured at a given level of compaction (gyrations/# of blows)
- Volumetrics (and stability/flow if applicable) determined
- Design binder content determined
- Moisture damage susceptibility determined

Performance Metrics

- Asphalt Content
- Air Voids
- Voids in the Mineral Aggregate
- Voids Filled with Asphalt
- Tensile Strength Ratio
- Marshall Stability and Flow

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Weakness in the present system of analysis?

COMBINED AGGREGATE PROPERTIES SELECTED TO HOPEFULLY CREATE STABLE/DURABLE AGGREGATE SKELETON

MIXTURE VOLUMETRICS USED TO HOPEFULLY SELECT AGGREGATE STRUCTURE/BINDER CONTENT THAT IS DURABLE

LIMITS ON RECYCLE % (PRIMARILY RAP) CONTROLLED BY METHOD SPECIFICATION TO ADDRESS PERCEIVED PROBLEMS WITH PAVEMENT CRACKING

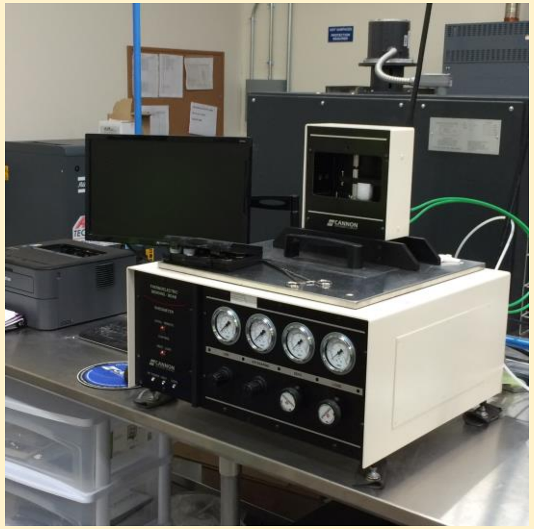
BINDER GRADE SELECTED FOR EITHER A BINDER GRADE BUMP DOWN(TO ACCOMMODATE HIGHER RECYCLE CONTENT) OR BUMPED UP TO ADDRESS HEAVY TRAFFIC LOADING (AND SOMETIMES CRACKING OF UNDERLYING MATT)

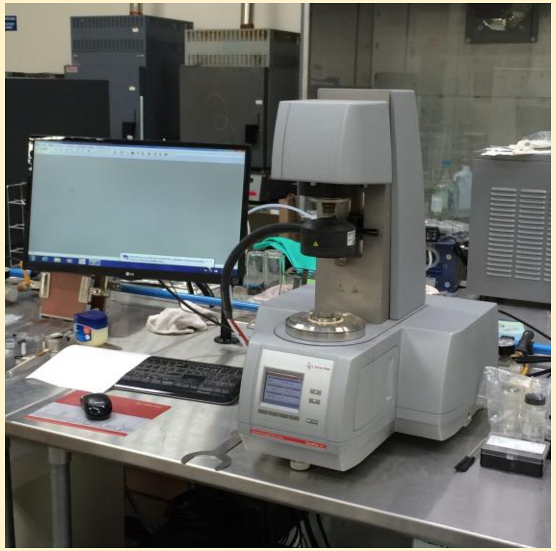
MOISTURE DAMAGE TEST TO DETERMINE IF ADDITIVE IS NEEDED OR NOT

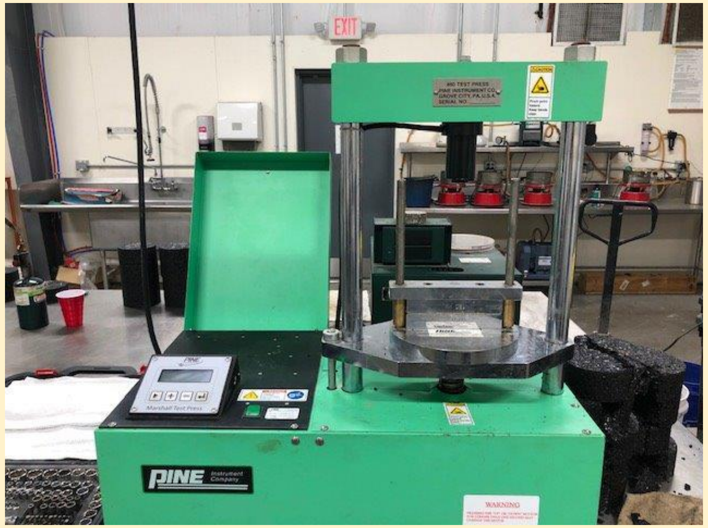
NO TESTING TO ADDRESS MIXTURE RUTTING SUSCEPTIBILITY

NO TESTING TO DETERMINE ASPHALT MIXTURE CRACKING SUSCEPTIBILITY

THE NEED FOR PERFORMANCE ENGINEERED MIX DESIGNS







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Balanced Mix Design Terms

- Performance Engineered Mix Design(PEMD)
- The Performance Engineered Mixture Design (PEMD) is a comprehensive engineering analysis and testing of asphalt mixtures on constituent materials and/or mixtures to meet or exceed the pavement design requirements and performance lifecycle.
- PEMD seeks to achieve the combination of binder, aggregate, and mixture proportions that will meet performance criteria for a diverse number of pavement distresses and a specified level of traffic, climate, and pavement.
- **The PEMD process for asphalt mixtures can be categorized as index-based PEMD or predictive PEMD**

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2020 FHWA Advancement of Asphalt Pavement Performance Stakeholder Listening Session

Notes

August 11-13, 2020

Location: Virtual Meeting

ATTENDEES: In total, twenty participants that represented academia (6 participants), State agencies (7 participants), FHWA (2 participants), and the asphalt paving industry (5 participants) attended the listening session. There were also three FHWA facilitators.

Observations, Key Themes, and Takeaways

A common observation that was expressed by the asphalt pavement community participants in the listening session was they are focusing on BMD with no near-term plans to move forward with the routine use of the Asphalt Mixture Performance Tester (AMPT) nor implementation of PRS.

Index Based PEMD

- The index-based PEMD process, which is similar to what many call the Balanced Mix Design (BMD) process, is an asphalt mixture design process that uses performance tests on appropriately conditioned specimens to address primary modes of distress while taking into consideration asphalt mixture aging, traffic, climate, and location of the mixture within the pavement structure.
- The BMD process focus has been on using performance tests to balance asphalt pavement rutting performance with durability/cracking performance; and, to make tradeoffs between the two distresses to maximize overall pavement performance.

Index-Based PEMD

- An index-based PEMD process relies on index parameters determined using performance tests on appropriately conditioned specimens to address multiple modes of distress. The index parameters should be correlated to field pavement performance using available (local) materials before they can be used by an agency in an index-based PEMD as go/no-go (pass/fail) design and acceptance criteria.

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WHY BALANCED MIX DESIGNS?

Our existing mix design process has limitations

Concerns about asphalt mixture performance and durability

Volumetric properties do not always equate to quality

Account for new and changing additives and materials

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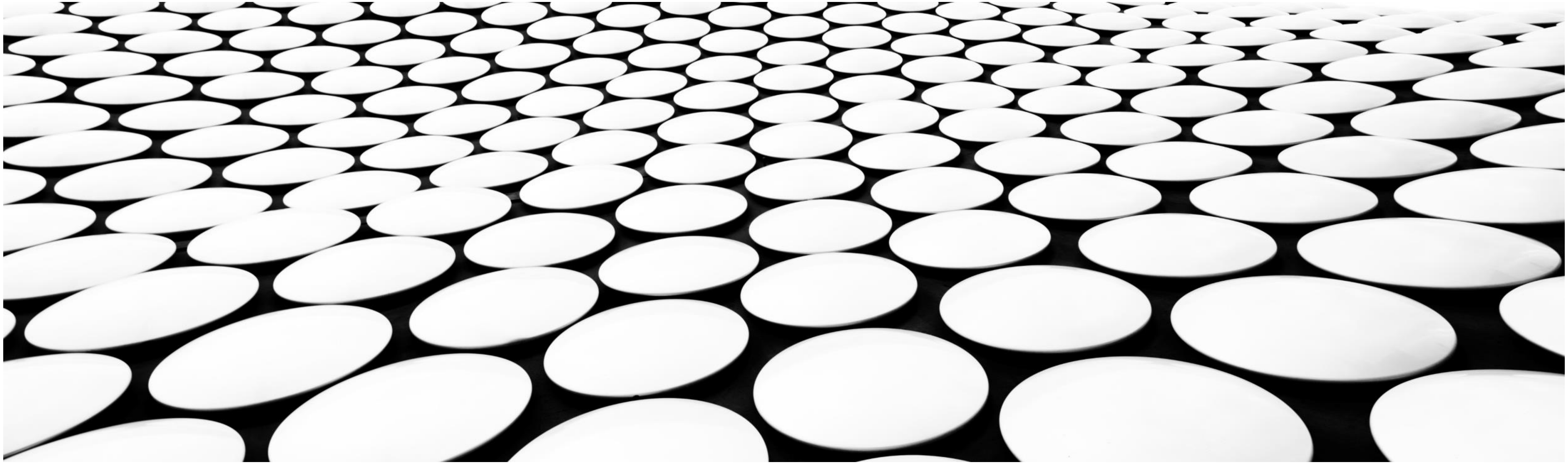
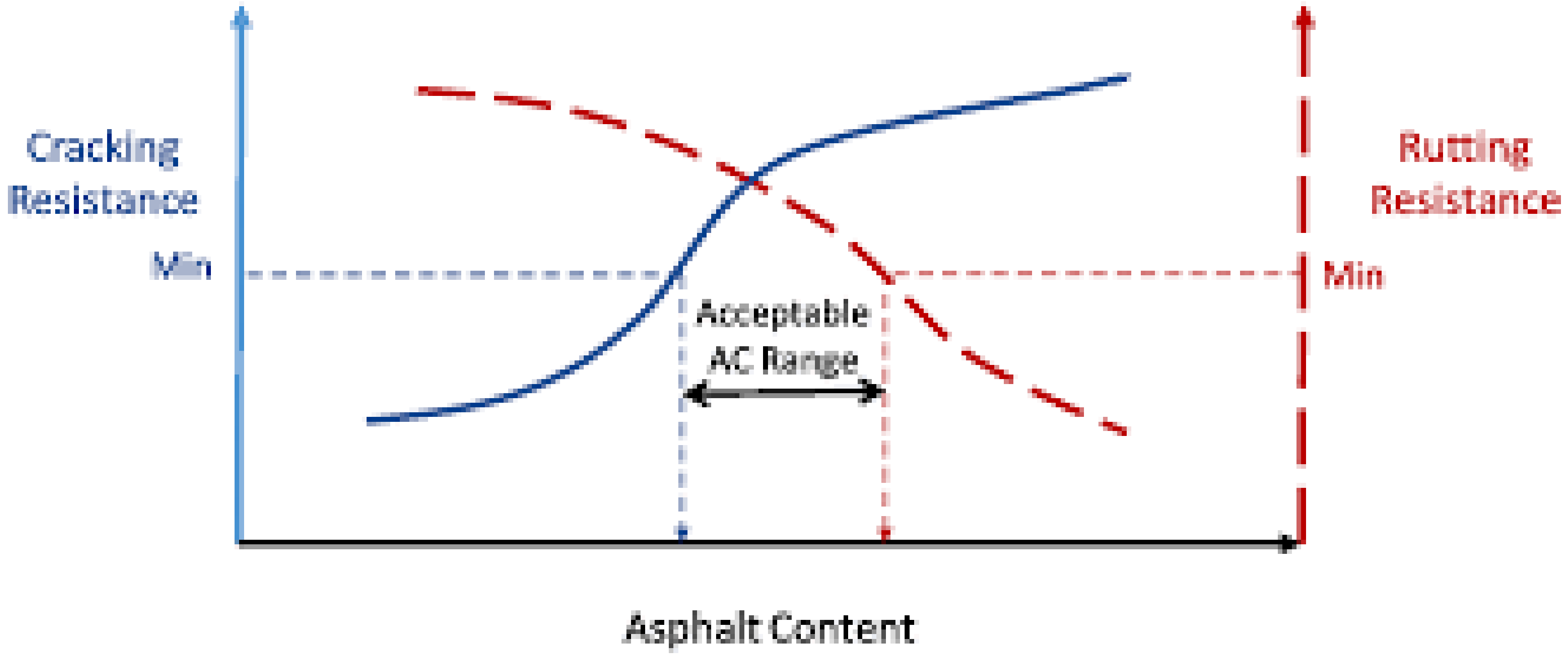
INTODUCTION TO BALANCED MIX DESIGSN

Evaluating Mixture Performance Based on Performance Testing



WHAT IS A BALANCED MIX DESIGN?



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REFERENCE DOCUMENTS

“Moving Towards Balanced Mix Design for Asphalt Mixtures”-NCAT

AASHTO Draft, “Standard Specification for Balanced Mix Design.”

AASHTO Draft, ”Standard Practice for Design of Asphalt Mixtures.”

ASTM D 8225,”Determination of Cracking Tolerance Index of Asphalt Mixture Using the Indirect Tensile Cracking Test at Intermediate Temperature.”

AASHTO TP 124-18,”Determining the Fracture Potential of Asphalt Mixtures Using the Flexibility Index Test (FIT).”

AASHTO T 324,”…Hamburg Wheel-Track Testing of Compacted Asphalt Mixtures”

AASHTO T 340,”…Determining Rutting Susceptibility of Hot Mix Asphalt (HMA) Using the Asphalt Pavement Analyzer (APA).”

NCAT Report 18-04,”Phase VI (2015-2017) NCAT Test Track Findings.”

WHAT IS A BALANCED MIX DESIGN?

In September 2015, the FHWA Expert Task Group on Mixtures and Construction formed a Balanced Mix Design Task Force.

This group defined balanced mix design (BMD) as "asphalt mix design using performance tests on appropriately conditioned specimens that address multiple modes of distress taking into consideration mix aging, traffic, climate and location within the pavement structure."

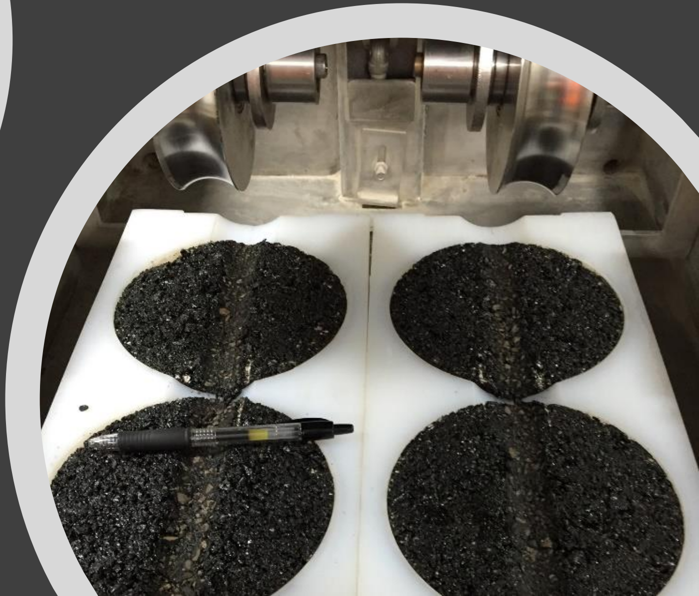
In short, BMD incorporates two or more mechanical tests such a rutting test and a cracking test to assess how well the mixture resists common forms of distress. (Source: "Moving Towards Balanced Mix Design for Asphalt Mixtures."-NCAT)

What are the modes of distress?

- RUTTING
- CRACKING
  - THERMAL CRACKING
  - REFLECTION CRACKING
  - BOTTOM-UP FATIGUE CRACKING
  - TOP-DOWN FATIGUE CRACKING
- MOISTURE SUSCEPTIBILTY

Definition of BDM

- **Mixes are designed to achieve a balance between rutting…**



Definition of BDM

- **…and cracking**

COMMONLY USED ASPHALT MIXTURE PERFORMANCE TESTS

Mixture Property	Laboratory Test	Test Standard
Thermal Cracking	Disk-Shaped Compact Tension Test	ASTM D7313-13
	Indirect Tensile (IDT) Test	AASHTO T 322-07
	Semi-Circular Bend (SCB) Test	AASHTO TP 105-13
	Thermal Stress Restrained Specimen Test	BS EN12697-4
Reflection Cracking	Disk-Shaped Compact Tension Test	ASTM D7313-13
	Texas Overlay Test	TxDOT Tex-248-F NJDOT B-10
Bottom-Up Fatigue Cracking	Direct Tension Cyclic Fatigue Test	AASHTO TP 107-14
	Flexural Bending Beam Fatigue Test	AASHTO T 321 ASTM D7460
	IDT Fracture Energy Test	N/A
	Illinois Flexibility Index Test	AASHTO TP 124-16
	SCB at Intermediate Temperature	LaDOTD TR 330-14 ASTM D8044-16
	Texas Overlay Test	TxDOT Tex-248-F
Top-Down Fatigue Cracking	Direct Tension Test	N/A
	IDT Energy Ratio Test	N/A
Rutting	Asphalt Pavement Analyzer	AASHTO T 340
	Flow Number	AASHTO TP 79-15
	Hamburg Wheel Tracking Test	AASHTO T 324
	Superpave Shear Tester	AASHTO T 320-07
	Triaxial Stress Sweep Test	AASHTO TP 116-15
Moisture Susceptibility	Hamburg Wheel Tracking Test	AASHTO T 324
	Tensile Strength Ratio	AASHTO T 283

TOP-DOWN FATIGUE IDEAL CT-INDEX TEST (ASTM D8225)

Source:"Moving Towards Balanced Mix Design for Asphalt Mixtures"-NCAT

NCAT Report 18-04 (Test Track Findings)

- Cracking tests for evaluation
  - Energy Ratio
  - Texas Overlay (TX-OT) test
  - NCAT modified Overlay Test (NCAT-OT)
  - Semi-circular bend test (SCB) (Louisiana method)
  - Illinois Flexibility Index (I-FIT) test
  - IDEAL Cracking Test (IDEAL-CT)

AASHTO Draft Specification for BMD

Standard Specification for

Balanced Mix Design

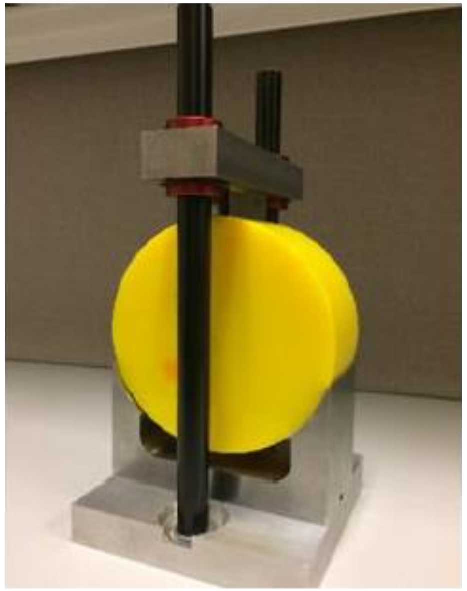
AASHTO Designation: M XXX-XX

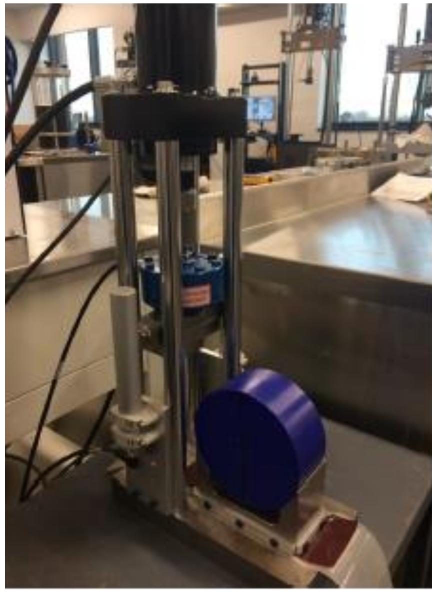
AASHTO

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

Rutting Tests

- **Asphalt Pavement Analyzer (APA) (AASHTO T340)**
- **Flow Number Test (AASHTO T378)**
- **Hamburg Loaded Wheel-Tracking Test (AASHTO T324)**
- **Hveem Stability Test (AASHTO T246)**
- **Superpave Shear Tester (AASHTO T320)**



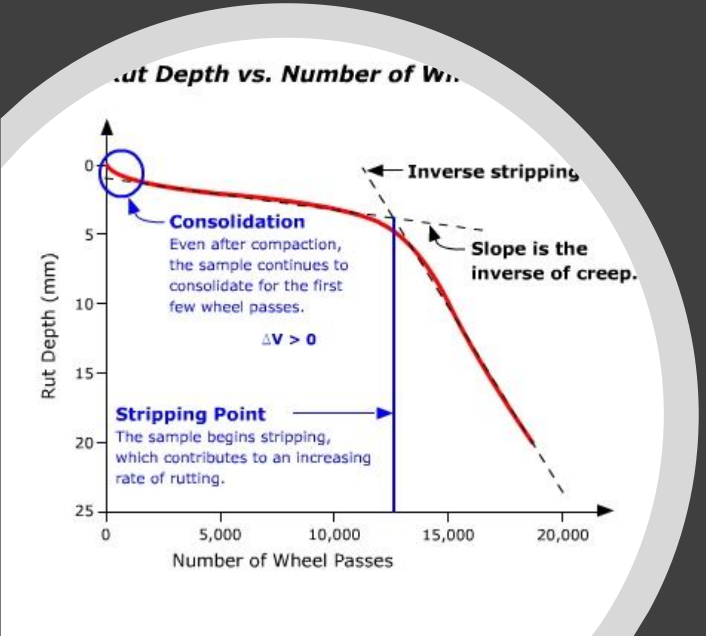


ADDITIONAL RUTTING TESTS ON THE HORIZON

- HIGH TEMPERATURE IDT
- IDEAL -RT
  - Cylindrical Specimen
    - 150 mm D x 62 mm H
  - Test Temperature
    - 50° C
  - Loading Rate
    - 50 mm/min
  - Rutting Parameter
    - Shear Strength, t_{max}

Cracking Tests

- BBR Mixture Bending Test (AASHTO TP125)
- Direct Tension Cyclic Fatigue Test (AASHTO TP107)
- **Disc-shaped Compact Tension Test (ASTM D7313)**
- Flexural Bending Beam Fatigue Test (ASTM D7313)
- **Illinois Flexibility Index Test (AASHTO TP124, Illinois Test Procedure 405)**
- **Indirect Tensile Asphalt Cracking Test (IDEAL-CT)(ASTM D8225-19)**
- Indirect Tensile Creep Compliance and Strength Test (AASHTO T322)
- Indirect Tensile Energy Ratio Test (no methodology listed)
- Indirect Tensile Fracture Energy Test (AASHTO Draft Procedures)
- **Overlay Test (TEX-248-F, NJDOT B-10)**
- Semi-Circular Bend Test at Intermediate Temperature (ASTM D8044) (Louisiana)
- Semi-Circular Bend Test at Low Temperature (AASHTO TP105)
- Uniaxial Thermal Stress and Strain Test (ASTM WK60626)



Moisture Damage Tests

- Hamburg Wheel-Tracking Test (Stripping Inflection Point) (AASHTO T324)
- Indirect Tensile Strength (AASHTO T283)
- Moisture Induced Stress Tester (MIST) (ASTM D7870)

AASHTO Draft Practice for BMD

Standard Practice for

Balanced Design of Asphalt Mixtures

AASHTO Designation: R xx-xx

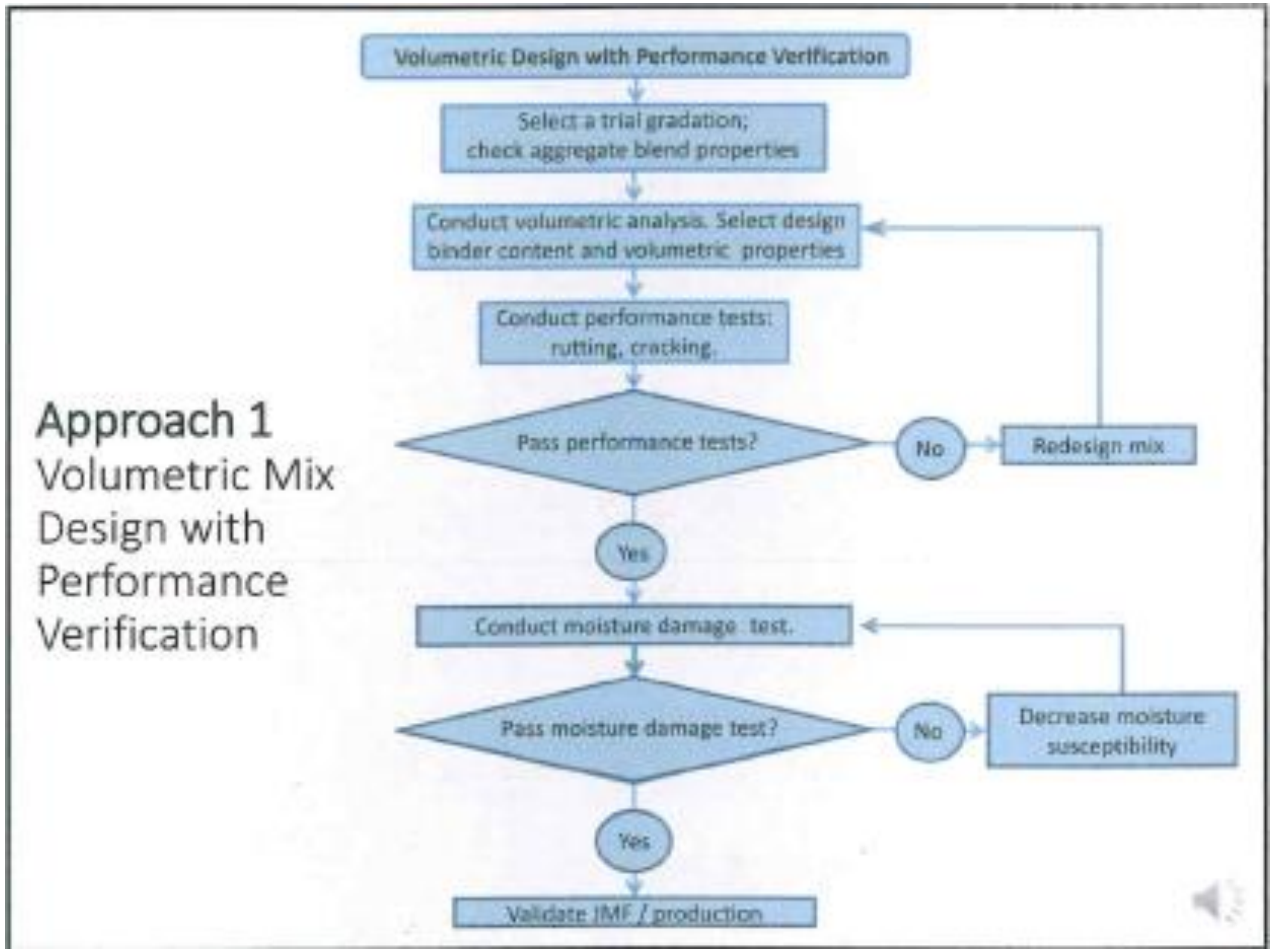
Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

BDM Approaches

AASHTO Draft Practice For Design Of Asphalt Mixtures

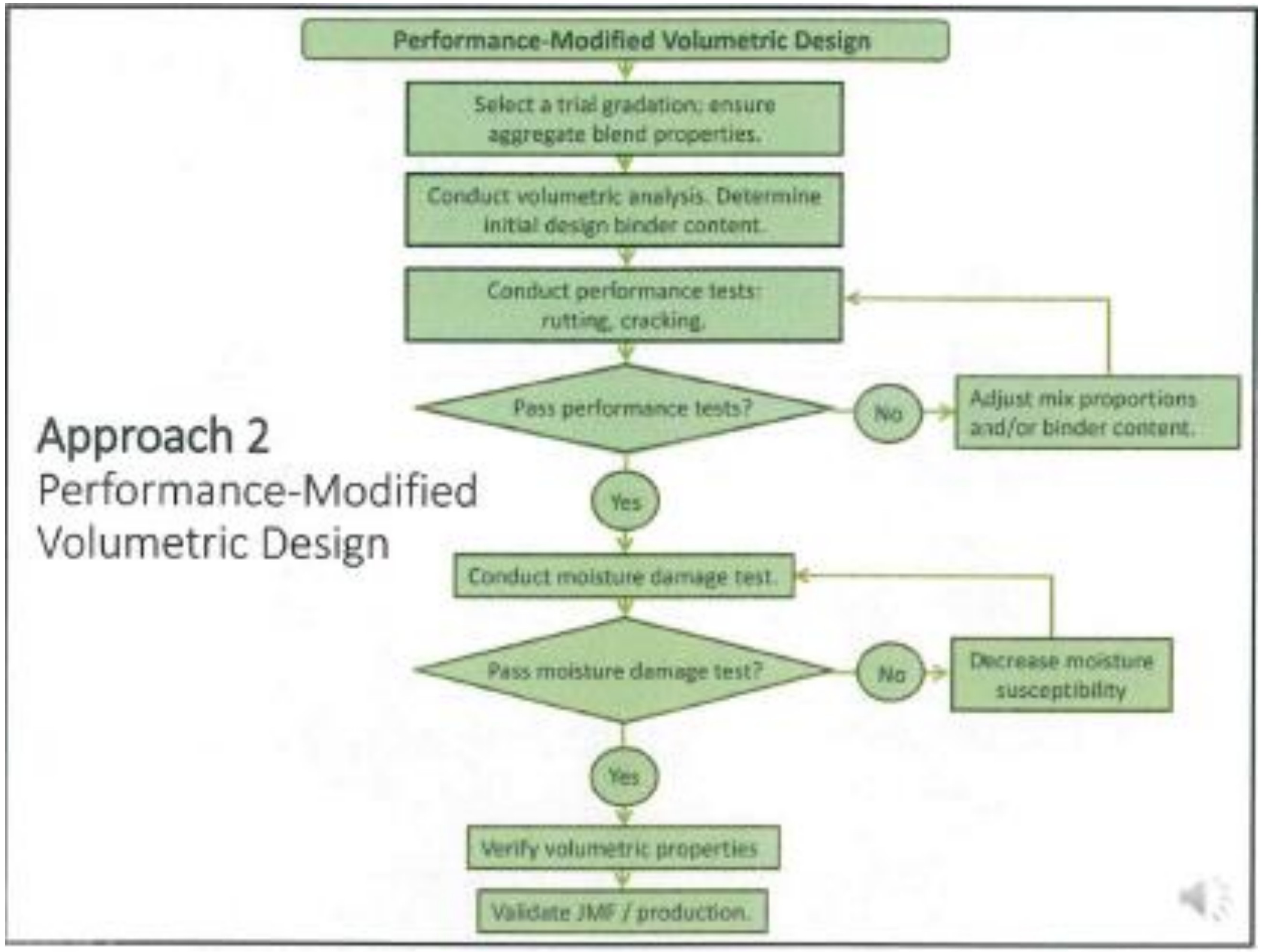
APPROACH "A"
(Volumetric Mix Design with Performance Verification)

- Start with current volumetric mix design method and determine optimum % binder
- Assess performance tests to determine rutting, cracking and moisture damage at this selected optimum % binder



APPROACH "B"
(Volumetric Design with Performance Optimization)

- Start with current volumetric mix design method to determine preliminary optimum % binder
- Mix performance tests conducted at preliminary optimum % binder and two (or more) additional binder contents
- Percent asphalt binder content that satisfies all cracking, rutting and moisture damage criteria identified as **FINAL OPTIMUM ASPHALT BINDER CONTENT**



APPROACH "C" (Performance-Modified Volumetric Mix Design)

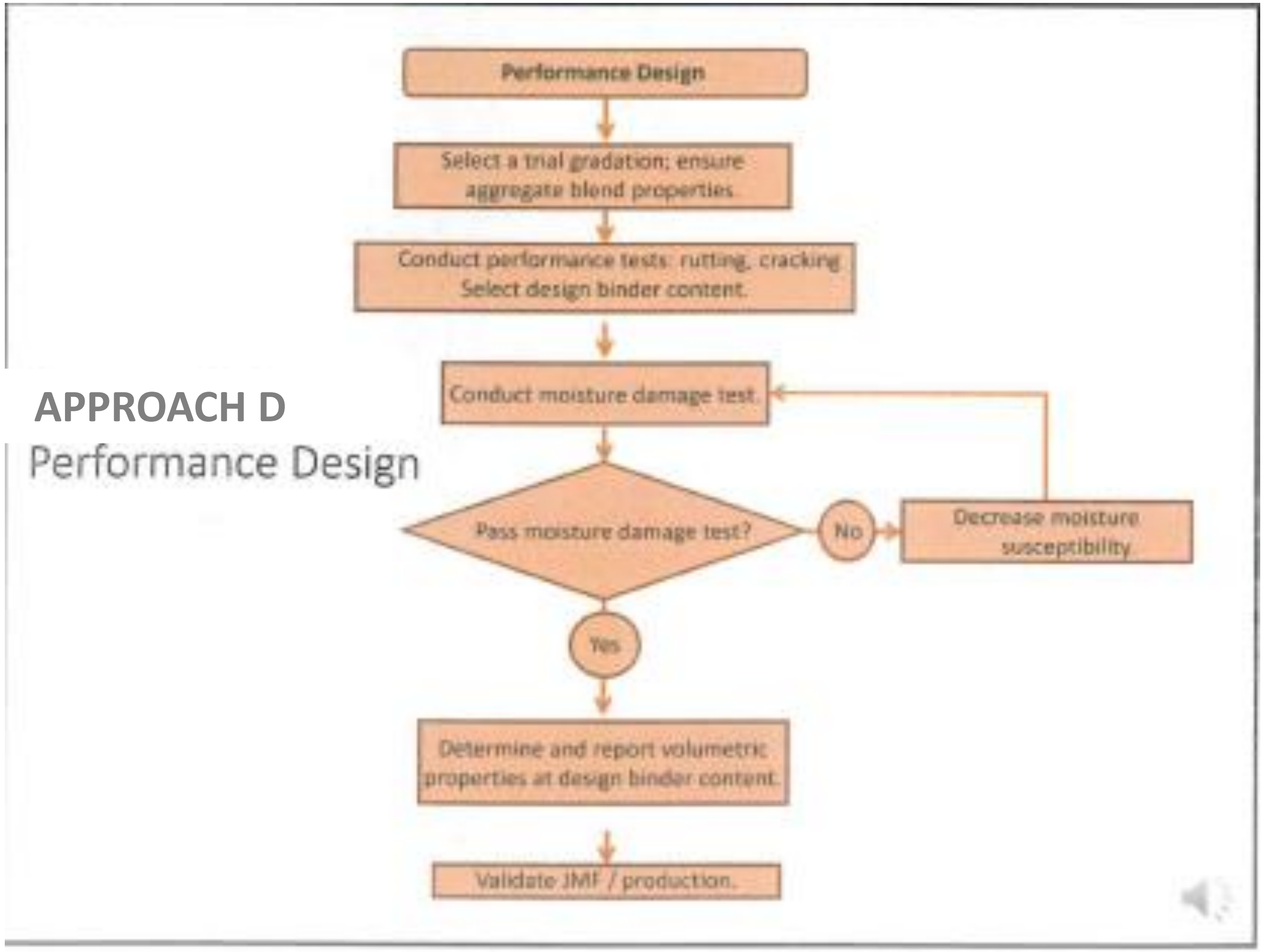
Begins with current volumetric mix design method to establish initial component material properties/proportions/% binder content

Performance test then used to adjust initial binder content or mix component properties or proportions until performance criteria are satisfied

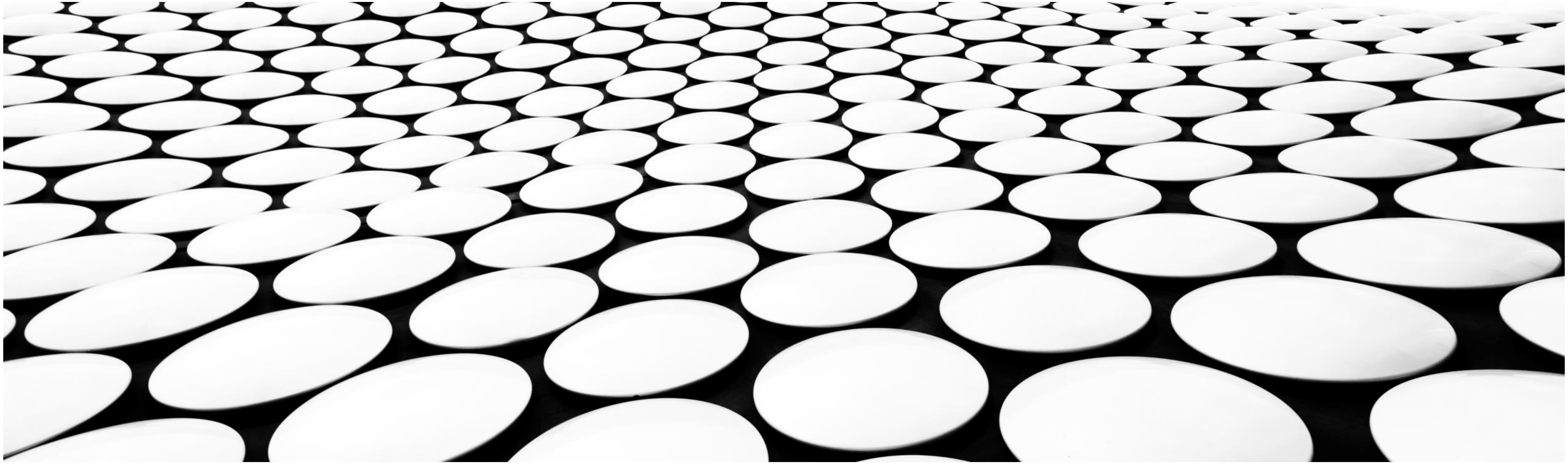
Focuses on satisfying performance test criteria and may not be required to meet all Superpave volumetric criteria

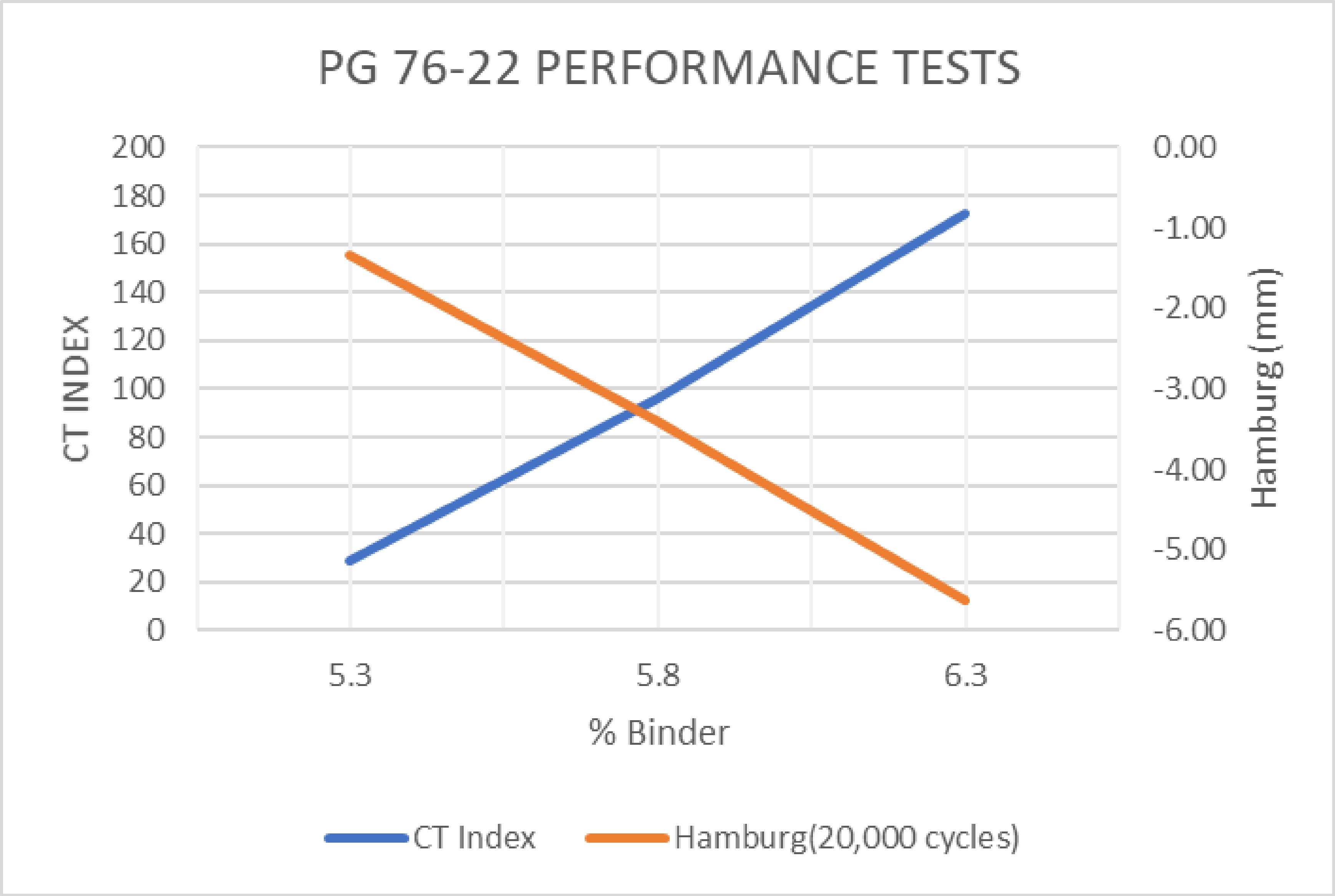
APPROACH "D"
(Performance Design)

- Mixture components and proportions established/adjusted based on performance analysis
- Limited or no requirements for volumetric properties
- Minimum requirements may be set for asphalt binder content and aggregate properties
- After lab test results meet performance criteria, mix volumetrics may be checked for use in production



Balanced Mix Design Test Methods




PG 76-22 PERFORMANCE TESTS
CT INDEX
200
180
160
140
120
100
80
60
40
20
0
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
Hamburg (mm)
5.3
5.8
6.3
% Binder
CT Index
Hamburg(20,000 cycles)

Examples of Index-Based Tests

RUTTING TESTS: Hamburg Wheel-Tracking Test(HWTT), Asphalt Pavement Analyzer(APA),Hveem Stability, Marshall Stability and Flow

- BEING LOOKED AT PRESENTLY: High Temperature Indirect Tensile Strength(IDT) and IDEAL-RT

CRACKING TESTS: Disc-Shaped Compact Tension (DCT),Illinois Flexibility Index (I-FIT), IDEAL CT-Index, Overlay Test (Texas and New Jersey), Semi-Circular Bend (SCB)

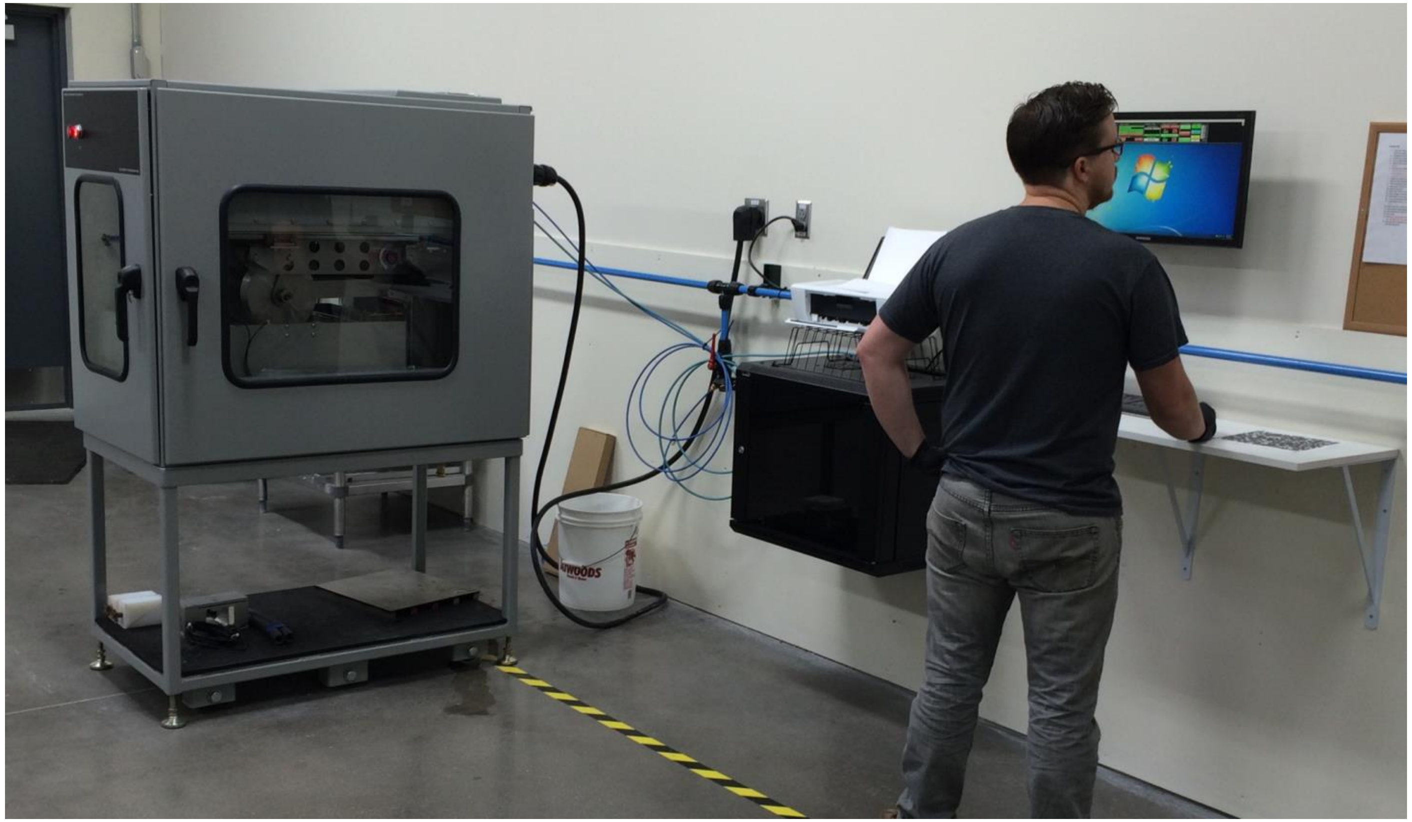
MOISTURE DAMAGE/STRIPPING TESTS: Hamburg Wheel-Tracking Test (HWTT),Indirect Tensile Strength, Immersion Compression Test, Retained Stability Test (Arkansas), Asphalt Film Retention Test(Boiling Test)

Rutting Tests for BMD

- RUTTING TEST GOAL:
  - Identify asphalt mixtures having potential for premature rutting failure
  - Predict asphalt mixture rutting during service life

Tests to Determine Rutting Susceptibility

- Hamburg Loaded Wheel-Tracking Test (AASHTO T324)
- Asphalt Pavement Analyzer (APA) (AASHTO T340)
- IDEAL-RT Test (presently being developed)
- High Temperature Indirect Tensile Strength Test (IDT)(ASTM D 6931??)
- Flow Number Test (AASHTO T378)
- Hveem Stability Test (AASHTO T246)
- Superpave Shear Tester (AASHTO T320)

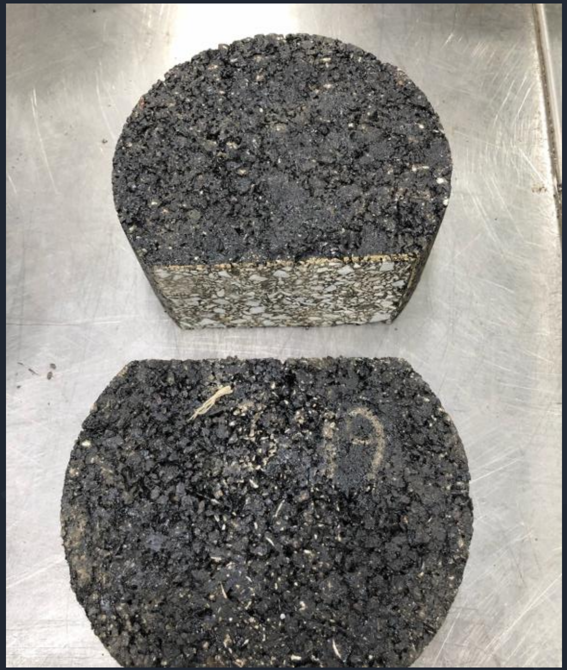


Rutting Susceptibility Test

- **Hamburg Loaded Wheel-Tracking Test (AASHTO T324)**

Hamburg Wheel Testing Sample Preparation

- Sample preparation:
  - Gyratory Specimens **(150 mm diameter)**
    - Compacted to 60 mm height (62.0 mm height target for IDEAL CT-Index)
    - Specimen thickness must be at least twice the nominal maximum aggregate size(T324,6.2.6.2)(that statement accommodates 25.0mm Base)
    - Compacted specimens cooled at room temperature till cool to touch
    - Specimen target air voids are 7.0 ± 0.5 % (AASHTO T324, Section 7.3)
      - Gmb (AASHTO T166), Gmm(AASHTO T209)
    - Lab Mixed Lab Compacted (LMLC):
      - Short term mechanical aging (AASHTO R30)
      - 4 hours @ 275̊F
  - Slabs
  - Field Cores



Hamburg Wheel Testing Sample Preparation

- Sample preparation:
  - Saw cut specimen ends such that when placed in mold there is no space between cut edges
  - Gap between molds should be no more than 7.5mm (0.3 in.)

Hamburg Wheel Testing

- Cut specimens mounted in molds then placed in water bath preheated to test temperature for ≥45 minutes,≤60 minutes
- Typical test temperature for area is 50 ̊C
- Wheel Loading is 158 ± 1 lbf steel wheel
- Rate of wheel movement is 52 ± 2 passes per minute
    - Pass=one way
- Start the test.
- The wheel tracking device will go to the 20,000 , some other predetermined number of passes or until the maximum target rut depth is achieved

States	Binder Grades	Test Temperatures
California	all	50°C
Colorado	PG 58-xx	45°C
	PG 64-xx	50°C
	PG 70-xx, PG 76-xx	55°C
Iowa	PG 58-xx	40°C
	PG 64-xx (or higher)	50°C
Illinois	all	50°C
Louisiana	all	50°C
Maine	all	50°C
Massachusetts	all	50°C
Montana	PG 58-xx	44°C
	PG 64-xx	50°C
	PG 70-xx	56°C
Oklahoma	all	50°C
Texas	all	50°C
Utah	PG 58-xx	46°C
	PG 64-xx	50°C
	PG 70-xx	54°C
Washington	all	50°C

California	PG 64-xx PG 70-xx PG 76-xx	Min. 15,000 passes at 12.5mm rut depth Min. 20,000 passes at 12.5mm rut depth Min. 25,000 passes at 12.5mm rut depth
Colorado	all	Max. 4.0mm rut depth at 10,000 passes
Iowa	all	Max. 8.0mm rut depth at 8,000 passes Min. 10,000 or 14,000 passes with no SIP
Illinois	PG 58-xx (or lower) PG 64-xx PG 70-xx PG 76-xx (or higher)	Max. 12.5mm rut depth at 5,000 passes Max. 12.5mm rut depth at 7,500 passes Max. 12.5mm rut depth at 15,000 passes Max. 12.5mm rut depth at 20,000 passes
Louisiana	Level 1 high traffic Level 2 medium/low traffic	Max. 6.0mm rut depth at 20,000 passes Max. 10.0mm rut depth at 20,000 passes
Maine	all	Max. 12.5mm rut depth at 20,000 passes Min. 15,000 passes with no SIP
Massachusetts	all	Max. 12.5mm rut depth at 20,000 passes Min. 15,000 passes with no SIP
Montana	all	Max. 13.0mm rut depth at 15,000 passes
Oklahoma	PG 64-xx PG 70-xx PG 76-xx	Min. 10,000 passes at 12.5mm rut depth Min. 15,000 passes at 12.5mm rut depth Min. 20,000 passes at 12.5mm rut depth
Texas	PG 64-xx PG 70-xx PG 76-xx	Min. 10,000 passes at 12.5mm rut depth Min. 15,000 passes at 12.5mm rut depth Min. 20,000 passes at 12.5mm rut depth

Examples of Rut Depth Criteria

Georgia DOT

Table 1 – GDOT HWTD Testing and Acceptance Criteria

PG Grade	Mix Type	Number of Passes	Maximum Rut Depth
PG 64-22 and PG 67-22	4.75 mm, 9.5 mm SP TP I, 9.5 mm SP TP II,	15,000	12.5 mm (0.5 inch)
PG 64-22 and PG 67-22	12.5 mm SP, 19 mm SP and 25 mm SP	20,000	12.5 mm (0.5 inch)
PG 76-22	All Mix Types	20,000	12.5 mm (0.5 inch)
Stripping Inflection Point (SIP) Shall Not Occur Prior to 15,000 Passes			

- Bituminous Construction Bulletin (October 27, 2015) to All Asphaltic Concrete Producers for Georgia Department of Transportation Projects

MoDOT

PG Grade High Temperature *	Minimum Wheel Passes	Maximum Rut Depth (mm)
58S-xx	5,000	12.5
64S-22	7,500	12.5
64H-22	15,000	12.5
64V-22	20,000	12.5

- Superpave Performance Testing and Increase Density – JSP
- 4.0 Hamburg Wheel Track. Hamburg Wheel Track testing will be completed in accordance with AASHTO T324 at test temperature of 50F and 62 mm specimen height

Hamburg Wheel Testing – Time to Completion

Specimen Fabrication, Cooling , Gmb Determination: **40 minutes**

Specimen cuts, putting in molds: **30 minutes**

Temperature conditioning of specimens: **45 minutes**

Machine Run Time:

- 20,000 passes(@52 passes/minute)taking **6.4** hours run time (TOTAL TIME=**8.3** hrs)
- 15,000 passes taking 4.8 hours run time (TOTAL TIME=6.7 hrs.)
- 10,000 passes taking 3.2 hours run time (TOTAL TIME=5.1 hrs.)
- 7,500 passes taking 2.4 hours run time (TOTAL TIME=4.3 hrs)

- With the time elapsed to accomplish Hamburg Testing, is there a need for a test that will yield (at least interim) test results for a confidence check?

Left Sample Max	
PASS COUNT	Value In MM
2000	2.571
3000	2.818
4000	3.217
5000	3.623
6000	3.996
7000	4.474
7500	4.755
8000	5.211
9000	6.480
10000	7.729
11000	9.480
12000	10.346
13000	11.455
14000	#N/A
15000	#N/A
16000	#N/A
17000	#N/A
18000	#N/A
19000	#N/A
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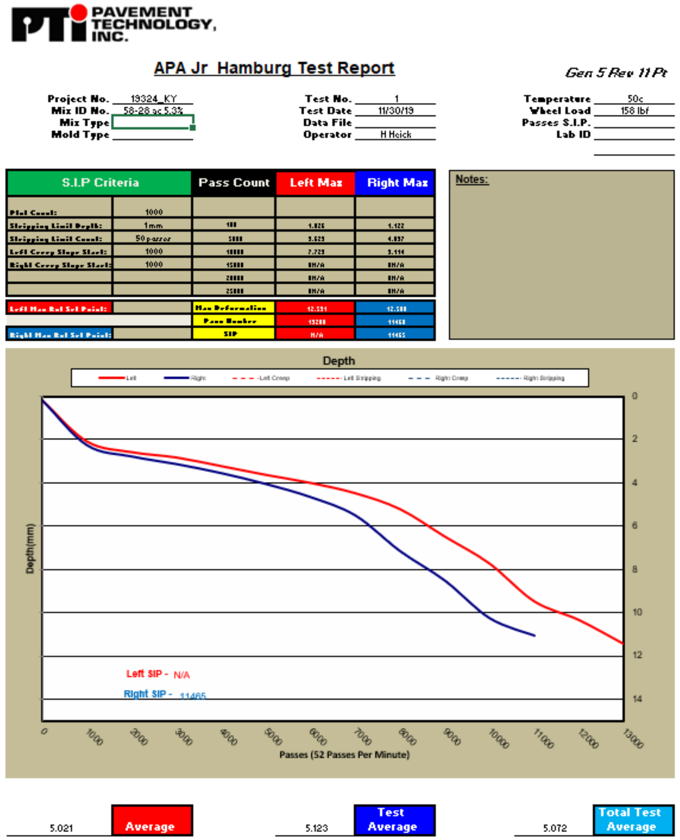
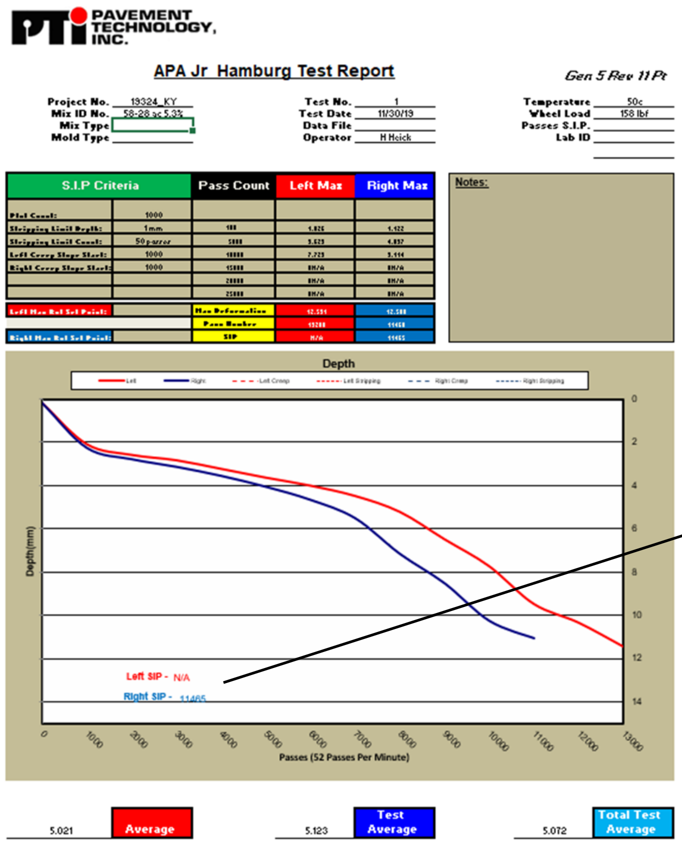
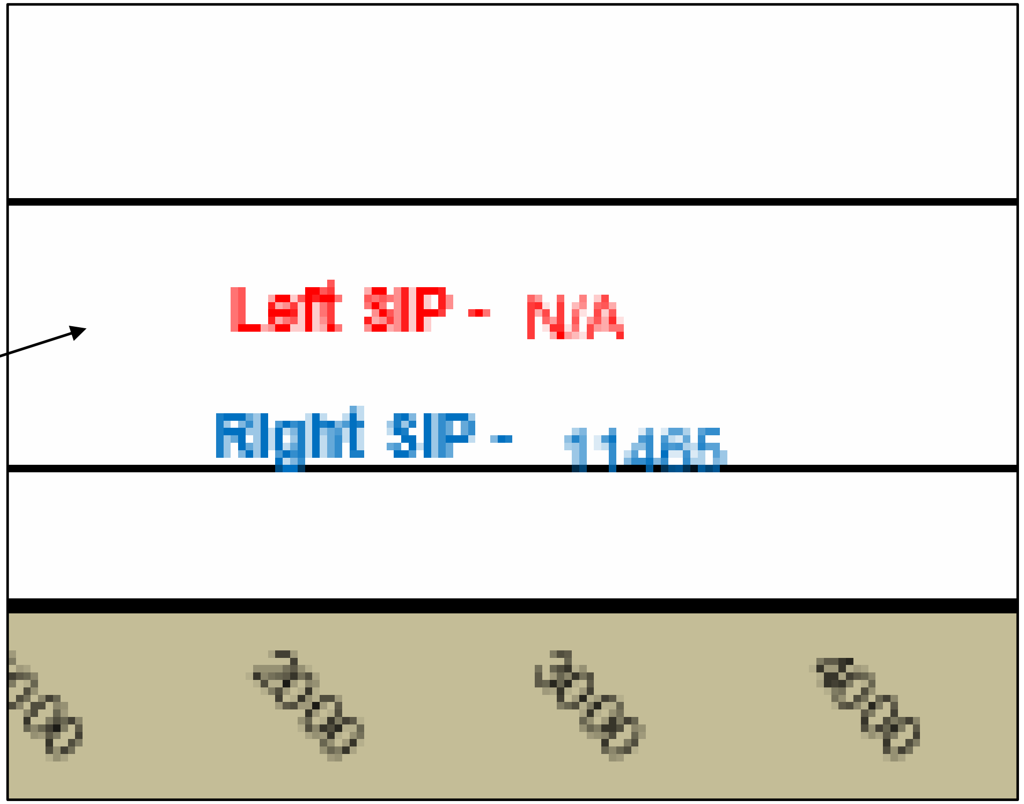
24000	#N/A
25000	#N/A



Right Sample Max	
PASS COUNT	Value In MM
2000	2.763
3000	3.116
4000	3.533
5000	4.037
6000	4.643
7000	5.492
7500	6.212
8000	7.141
9000	8.502
10000	10.238
11000	11.041
12000	#N/A
13000	#N/A
14000	#N/A
15000	#N/A
16000	#N/A
17000	#N/A
18000	#N/A
19000	#N/A
20000	#N/A
21000	#N/A
22000	#N/A
23000	#N/A
24000	#N/A
25000	#N/A

Hamburg Data Output



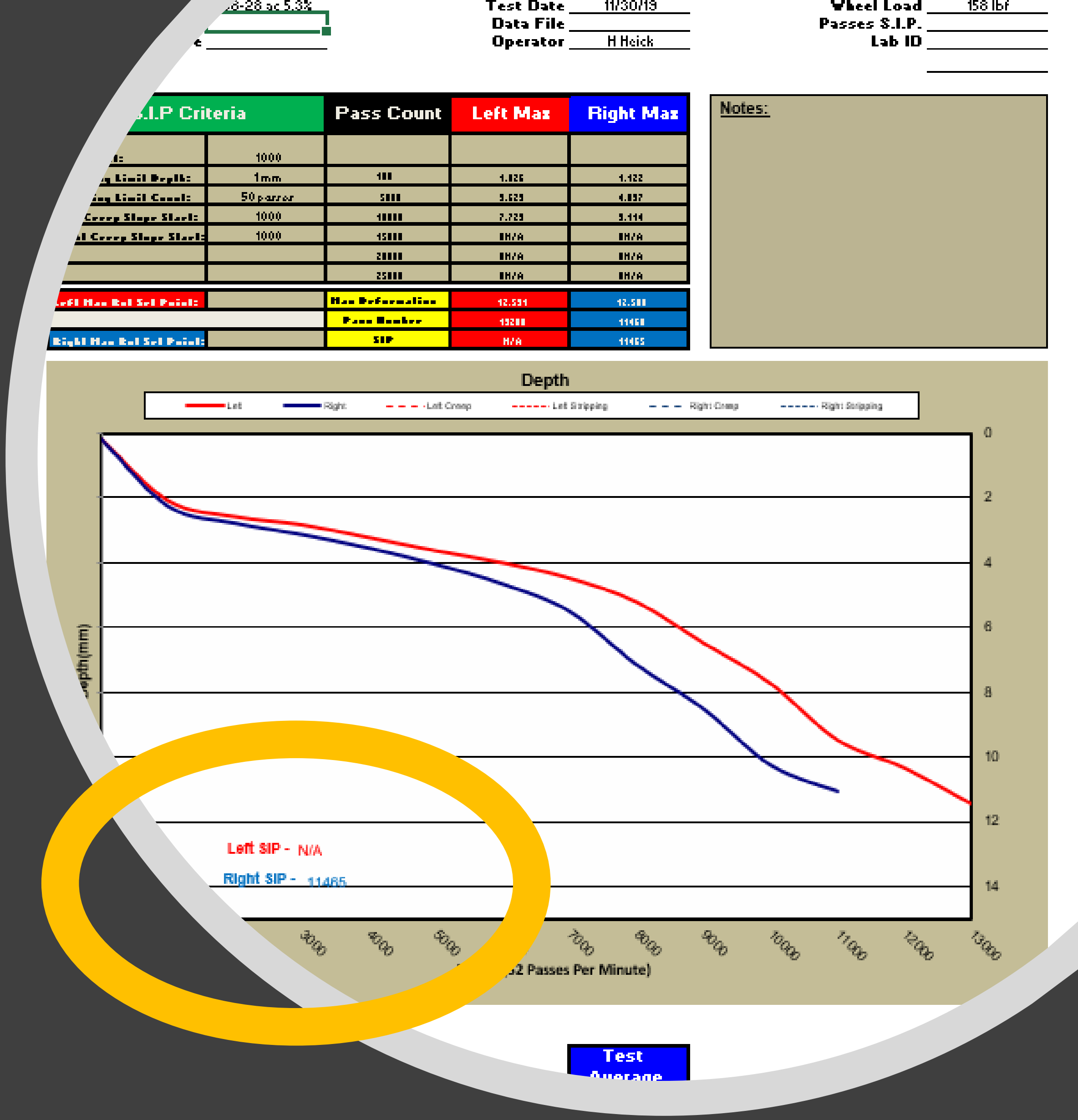


Hamburg Wheel Tracking INDICATED SIP

Stripping Inflection Point (SIP)

Hamburg Wheel Tracking INDICATED SIP

- A 6-point polynomial equation is used to calculate the SIPs up to 20k and well beyond.
- Even if you don't have a SIP between 0 and 20k the arithmetic still calculates out to a predicted SIP if it sees a slight change toward the end of the test
- In short, sometimes you will see the SIP within your 20k pass test and if it didn't happen before that it still tells us what it would be if you had kept running
- You will not always have a SIP with every test



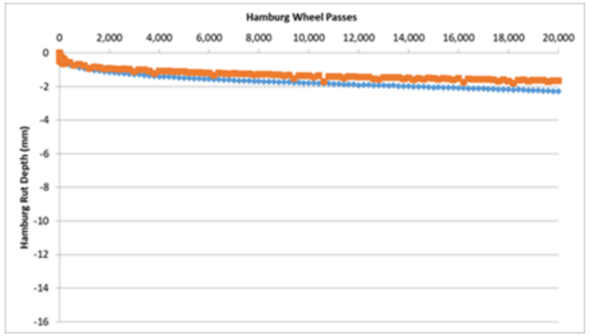


Figure 2: Example 1 – SIP greater than 20,000 passes

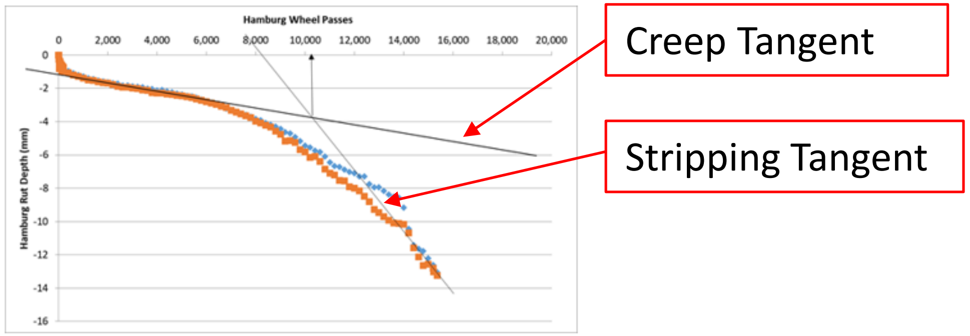


Figure 3: Example 2 – With SIP during test

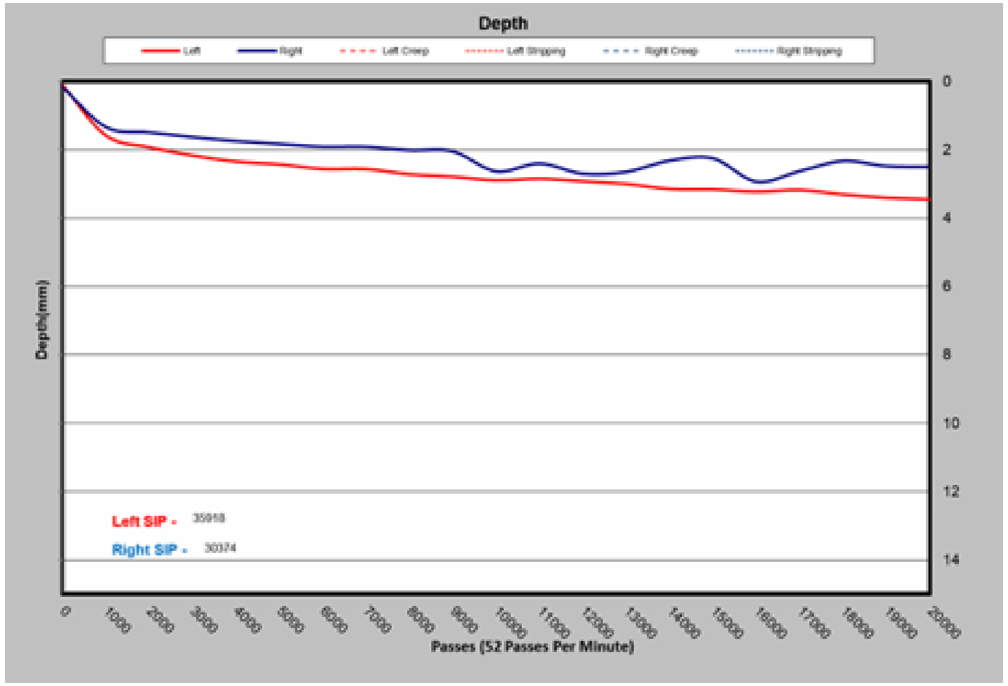


Figure 1: Provided Data – SIP greater than 20,000 passes

Indicated SIP Examples

- Example graph (top left) does <u>not</u> show signs of stripping
- Example graph (bottom left) <u>does</u> show signs of stripping
- Stripping can be seen in a sharp turn in the rutting curve towards failure. There would then be two distinct tangents, the creep tangent and the stripping tangent.
- For the example on the bottom left – the SIP would be about 10,000 passes since that is the intersection of the creep tangent and the stripping tangent

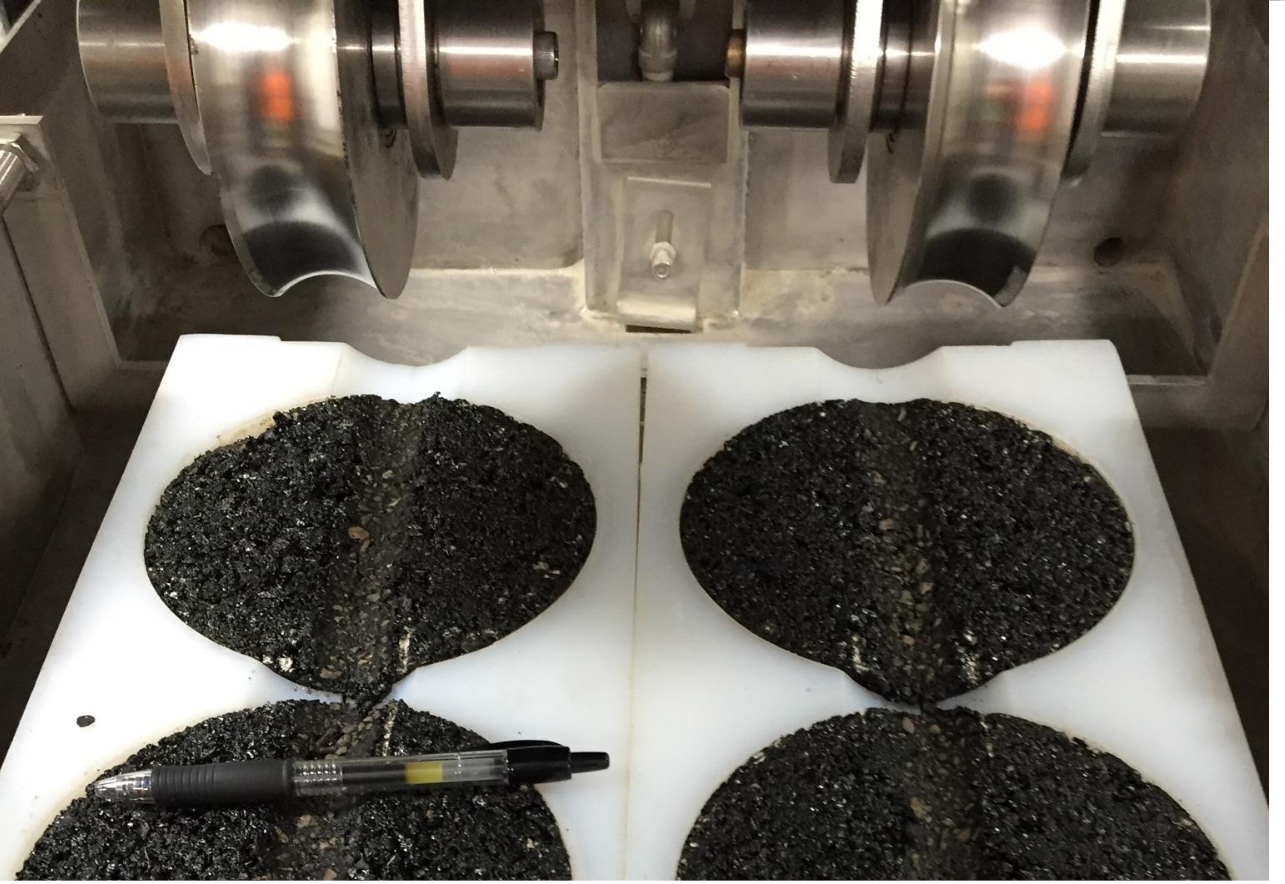
NCAT Report 18-04

PHASE VI (2015-2017) NCAT TEST TRACK FINDINGS

APA Criteria from Various States

NCAT TEST TRACK FINDINGS NCAT REPORT 18-04

- Popularity of the Hamburg Wheel Tracking Test has increased in recent years and numerous state SOT's now have Hamburg requirements for mix design approval
- Although there are no national criteria for Hamburg results, many highway agencies set the minimum rut depth between 4 and 12.5 mm at 20,000-wheel passes
- NCAT conducted the Hamburg test in accordance with AASHTO T 324 at 50° C on 18 mixtures from the fourth cycle
- The Hamburg results correlated reasonably well (R^2 = 0.74) with rutting measurements on the track (5).
- None of the test sections had any evidence of moisture damage



Asphalt Pavement Analyzer (APA) Loaded Wheel-Tracking Test (AASHTO T340)

APA Wheel Testing Sample Preparation

- Gyratory Specimens (150 mm diameter)
  - Compacted to 75 mm height
  - Compacted specimens cooled at room temperature (approx. 25̊C for min. of 3 hrs.)
  - Specimen target air voids are 7.0 ± 0.5 % (AASHTO T340, Section 4.3.2)
    - Gmb(AASHTO T166), Gmm(AASHTO T209)
  - Lab Mixed Lab Compacted (LMLC)
  - Short term aged
    - Short term mechanical aging (AASHTO R30)
    - 4 hours @ 275̊F
- Slabs
- Field Cores

Asphalt Pavement Analyzer (APA) Wheel Testing

- Specimens mounted in molds then placed in chamber preheated to test temperature for 6 hours(min.), 24 hours (max.) to precondition.(T340, 7.2)
- Test temperature is high standard PG grade
- Loading is 100 psi hose pressure with 100 lbf load on the hose(T340, 8.1)
  - FAA P401 spec now has 250 lbf/250 psi hose pressure
- Rate of wheel movement is 60 cycles per minute
  - Cycle=Forward and Back
- Start the test.
- The wheel tracking device will go to the 8000 , some other predetermined number of passes or until the maximum target rut depth is achieved (2 hours 13 minutes)

ALABAMA DEPARTMENT OF TRANSPORTATION

DATE: August 16, 2019 Job Special Provision No. XX-XXXX

EFFECTIVE DATE: Month X, XXXX

SUBJECT: Performance Based Asphalt Mix Design

Alabama Standard Specifications, 2018 Edition, SECTION 424 Shall be amended as follows:

SECTION 424
PERFORMACED BASED ASPHALT MIXES

APA run at 67̊C,100 psi, 100 lbf

2. Resistance to Rutting (Asphalt Pavement Analyzer and Hot Indirect tensile strength)

All mixes shall be designed to exhibit an average rut depth of less than 4.0 mm when tested according to ALDOT-401 RUTTING SUSCEPTIBILITY DETERMINATION OF ASPHALT PAVING MIXTURES USING THE ASPHALT PAVEMENT ANALYZER in the testing manual, and constructed to have an ultimate strength not less than 17 psi when tested by ALDOT XXX Hot Indirect Tensile Test

Designation: D6931 – 17

Standard Test Method for
Indirect Tensile (IDT) Strength of Asphalt Mixtures[1]

Tests to Determine Rutting Susceptibility

High Temperature Indirect Tensile (IDT)Strength Test

ASTM D6931

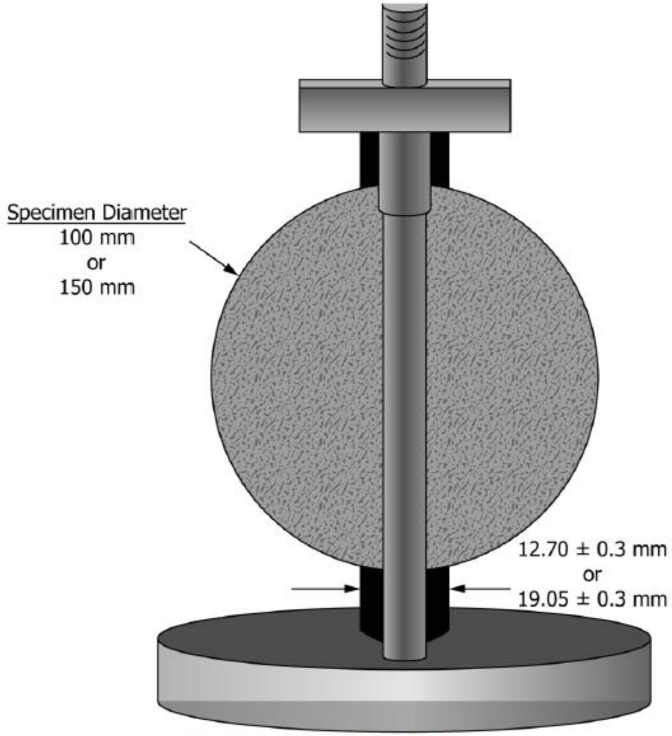


FIG. 1 Diagram of an IDT Strength-Loading Fixture

High Temperature IDT Sample Preparation

- Gyratory Specimens
  - **(ASTM D6931),**for 150mm diameter specimens 75mm min. specimen height
  - **(Proposed),** If nominal max. aggregate is < 1.0”(25.0mm)Compacted to 62±1mm height if nom. max. ≥1.0” compacted to 95±1mm
  - Prepare three specimens in accordance with AASHTO T312
  - Lab Mixed Lab Compacted (LMLC):
    - Short term mechanical aging (AASHTO R30)
    - 4 hours @ 275°F
  - Plant Mixed Lab Compacted
    - No additional aging
  - Specimen target air voids are 7.0 ± 0.5 % (AASHTO T324, Section 7.3)
    - Gmb (AASHTO T166), Gmm(AASHTO T209)
  - Measure and record specimen height at three locations .
  - Measure and record specimen diameter

High Temperature IDT Specimen Testing

Prepared specimens conditioned in 50°C (122°F) forced draft oven for 2 hours prior to testing

Specimens positioned on loading strips and 2 in./min vertical load applied to specimen. Record the maximum load

HTIDT Strength= 2 x Max. Load / (π x diam. x height)

Production testing time ~ 3 hours

High Temperature IDT Data Sheet

DATE: 2/5/20

Contractor: LPC@ Avoca

Project # 195324 – KY

Mix Type: CL3 Asph Surface 0.38 76-22

Technician: E.F.

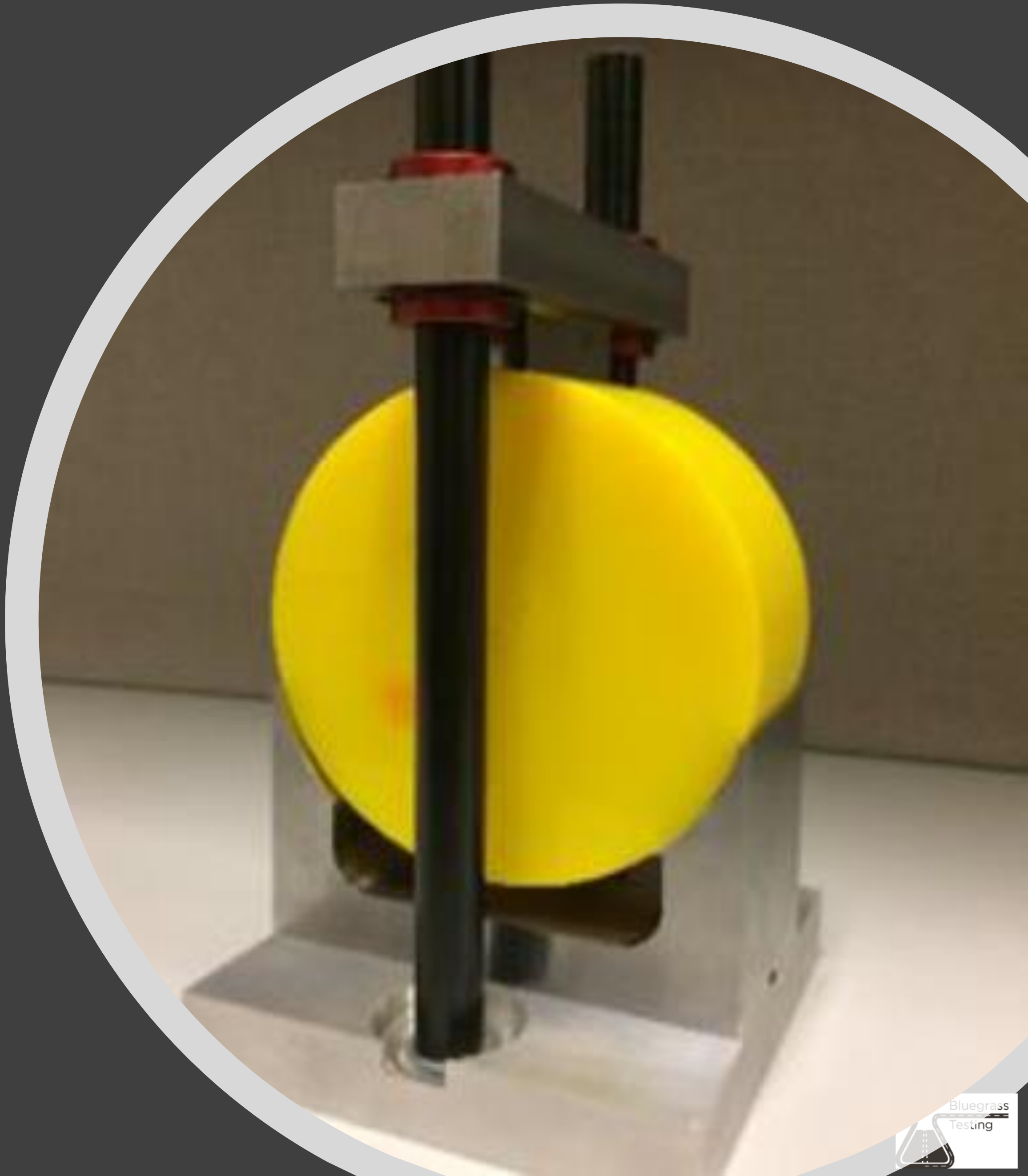
Average (w/PG 76-22)=55.5 psi

Test Temperature (F°): 122

Specimen #		1	2	3
Average Diameter of Specimen	(inches)	5.909	5.900	5.906
Average Height of specimen	(inches)	2.42	2.44	2.43
Maximum Load	(lbf)	1209.4	1334.1	1211.1
HTIDT STRENGTH 2* Max Load/3.141*D*H		53.9	59.0	53.7

Tests to Determine Rutting Susceptibility

- IDEAL-RT Test



IDEAL Rutting Test

Texas A&M Transportation Institute

Fujie Zhou, PhD, P.E.

ASTM D04.26 Subcommittee; June 6, 2019

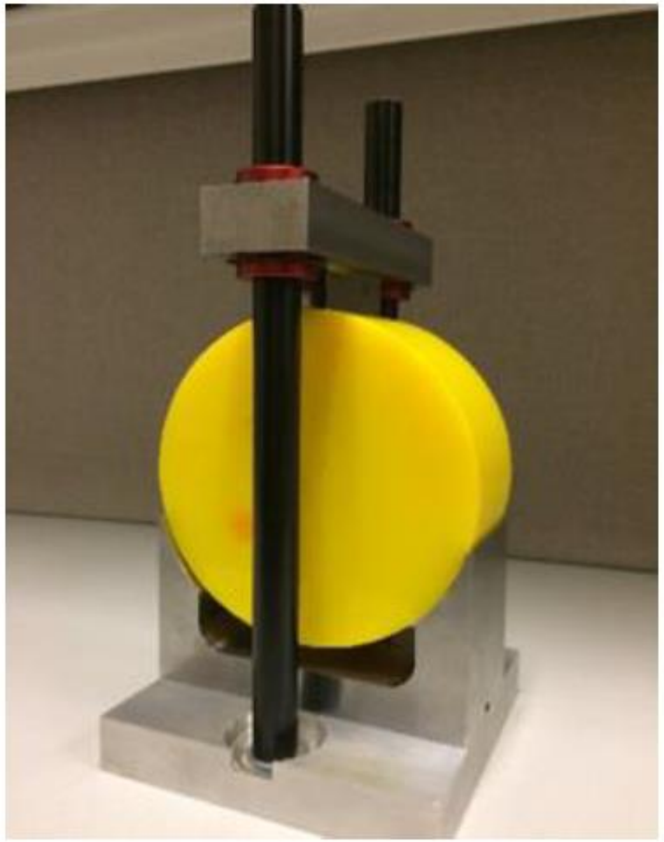
Introduction

- Why a new rutting test?
  - Rutting is a safety issue: hydroplaning and wet weather crashing.
  - Balanced mix design
    - Rutting may come soon
  - Neither Hamburg test nor APA is practical for being used for QC/QA testing.

- Need a simple, shearing and performance-related rutting test.

Development of IDEAL-RT : Test Conditions

- IDEAL-RT
  - Cylindrical specimen:
    - *150 mm Diam. X 62 mm high*
  - Test temperature:
    - *50°C (or others)*
  - Loading rate:
    - *50 mm/min.*
  - Rutting parameter:
    - *Shear strength,* τ_{max}



? Tests to Determine Rutting Susceptibility?

The Hamburg Loaded Wheel test has shown good test result comparisons with actual indicated rutting in the field. It takes a good period to secure test results from the Hamburg but does its strength in indicating rutting warrant that states move forward with it as their bedrock rutting test?

With the time needed to complete a Hamburg Loaded Wheel Test or an Asphalt Pavement Analyzer (APA) Test is there a need for a more rapidly performed test as a (go)/(no go) (at the least) that will indicate rutting susceptibility?

If rutting is a function of shearing stresses, is the IDEAL RT Test (shear strength indicator) a better indicator than a High Temperature IDT (tensile strength indicator)?

Crack Testing

Balanced Mix Design Test Methods

Currently 13 Crack Test Methods

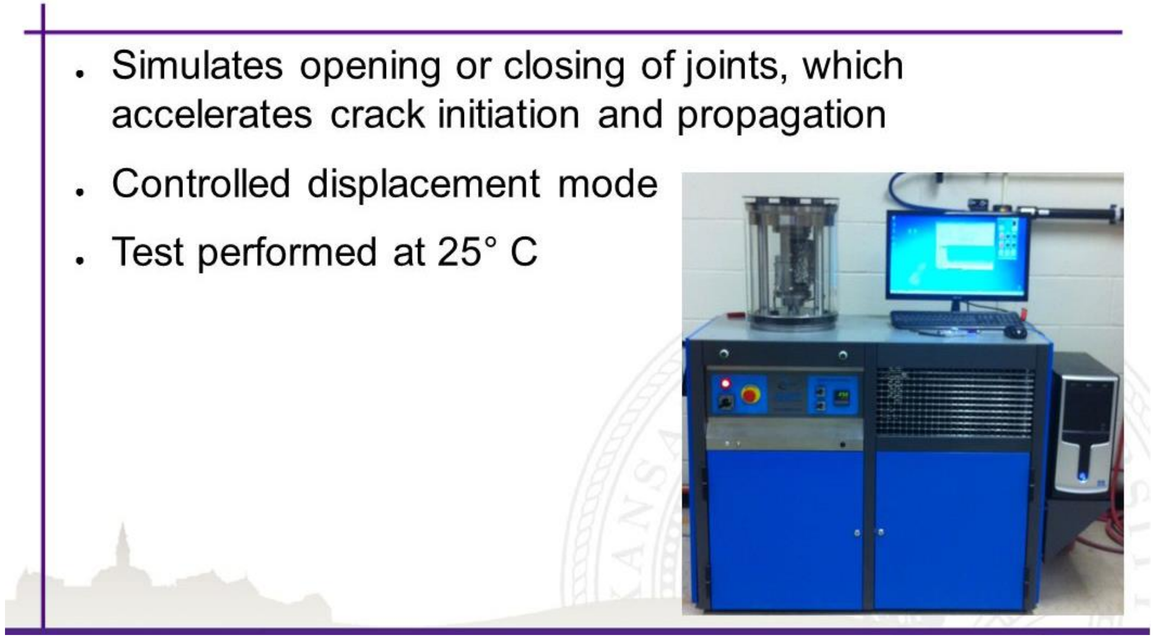
- BBR Mixture Bending Test (AASHTO TP125)
- Direct Tension Cyclic Fatigue Test (AASHTO TP107)
- **Disc-Shaped Compact Tension Test (ASTM D7313)**
- Flexural Bending Beam Fatigue Test (AASHTO T321)
- **Illinois Flexibility Index Test (AASHTO TP124, Illinois Test Procedure 405)**
- **Indirect Tensile Asphalt Cracking Test (IDEAL CT-INDEX)(ASTM D8225-19)**
- Indirect Tensile Creep Compliance and Strength Test (AASHTO T322)
- Indirect Tensile Energy Ratio Test (No methodology listed)
- Indirect Tensile Fracture Energy Test (AASHTO Draft Procedure)
- **Overlay Test (TEX-248-F, NJDOT B-10)**
- **Semi-Circular Bend Test at Intermediate Temperature(ASTM D8044)**
- Semi-Circular Bend Test at Low Temperature (AASHTO TP105)
- Uniaxial Thermal Stress and Strain Test (ASTM WK60626)

Types of Cracking

- THERMAL CRACKING
- REFLECTIVE CRACKING
- BOTTOM-UP FATIGUE CRACKING
- TOP-DOWN FATIGUE CRACKING

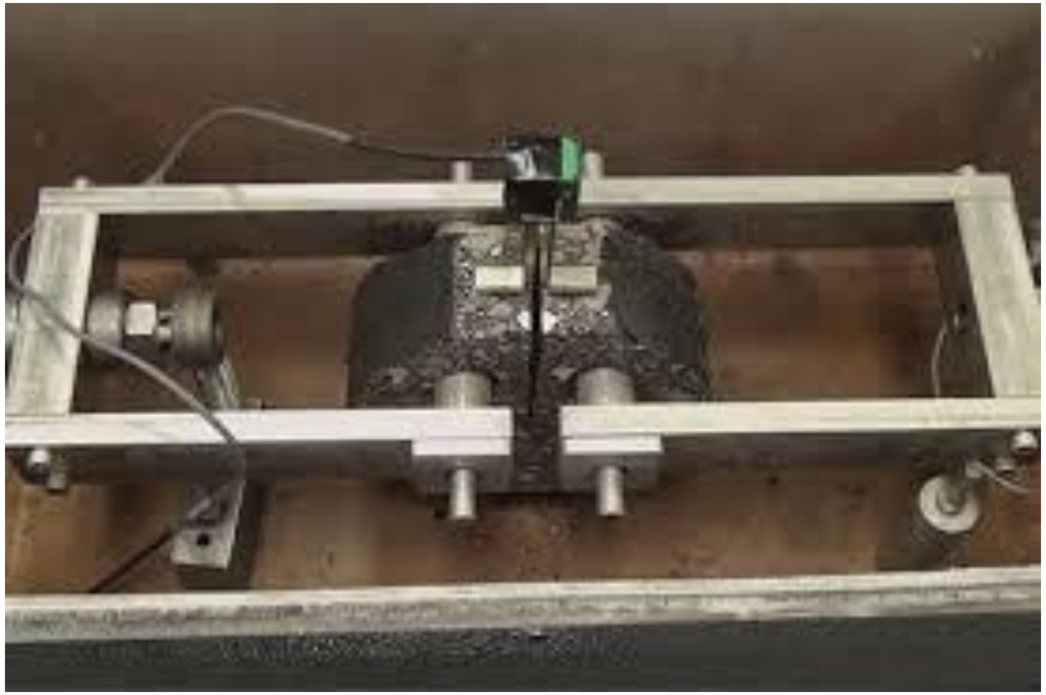
CRACKING TEST METHODS

- Cracking tests can be categorized by the mechanism in crack initiation and propagation:
  - TOP-DOWN CRACKING:
    - Flexibility Index (I-FIT)
    - Indirect Tensile Asphalt Cracking Test (IDEAL-CT)
  - BOTTOM-UP CRACKING:
    - Flexibility Index (I-FIT)
    - Texas Overlay Test
  - THERMAL CRACKING:
    - Disk-Shaped Compact Tension Test (DCT)
    - Flexibility Index (I-FIT)

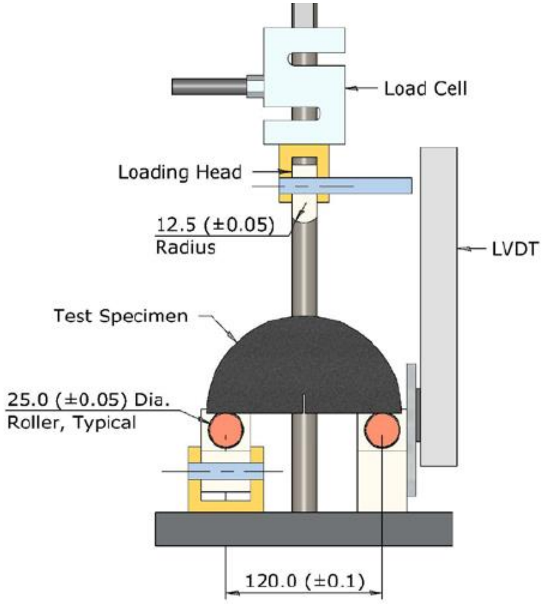


Texas Overlay Test (TEX-248-F)

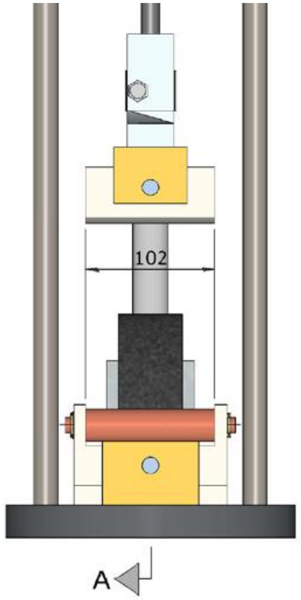
Disc-Shaped Compact Tension Test Device (Testquip)



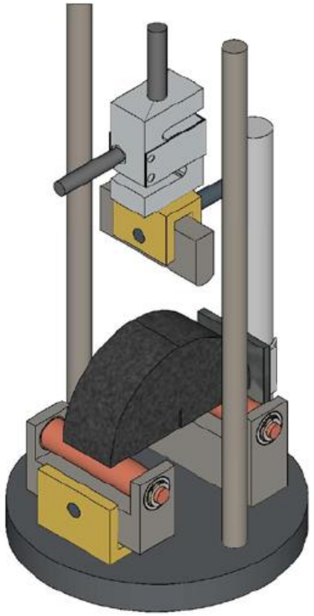
Disc-Shaped Compact Tension Test (DCT) ASTM D7313



SECTION A-A



ELEVATION



ISOMETRIC VIEW

Flexibility Index (IFIT)
AASHTO TP124

Flexibility Index (IFIT) AASHTO TP124

- LAB PRODUCED SPECIMENS
  - AIR VOIDS 7.0 ± 0.5 %
  - SPECIMENS:
    - Diameter 150mm, one gyratory compacted to 160mm, with four specimens secured from the middle OR
    - Diameter 150mm, two gyratory compacted to ≥115mm, with two specimens secured from the middle of each gyratory
    - Four individual I-FIT test specimens
    - Ligament length/thickness measured
    - Bulk specific gravity by AASHTO T166

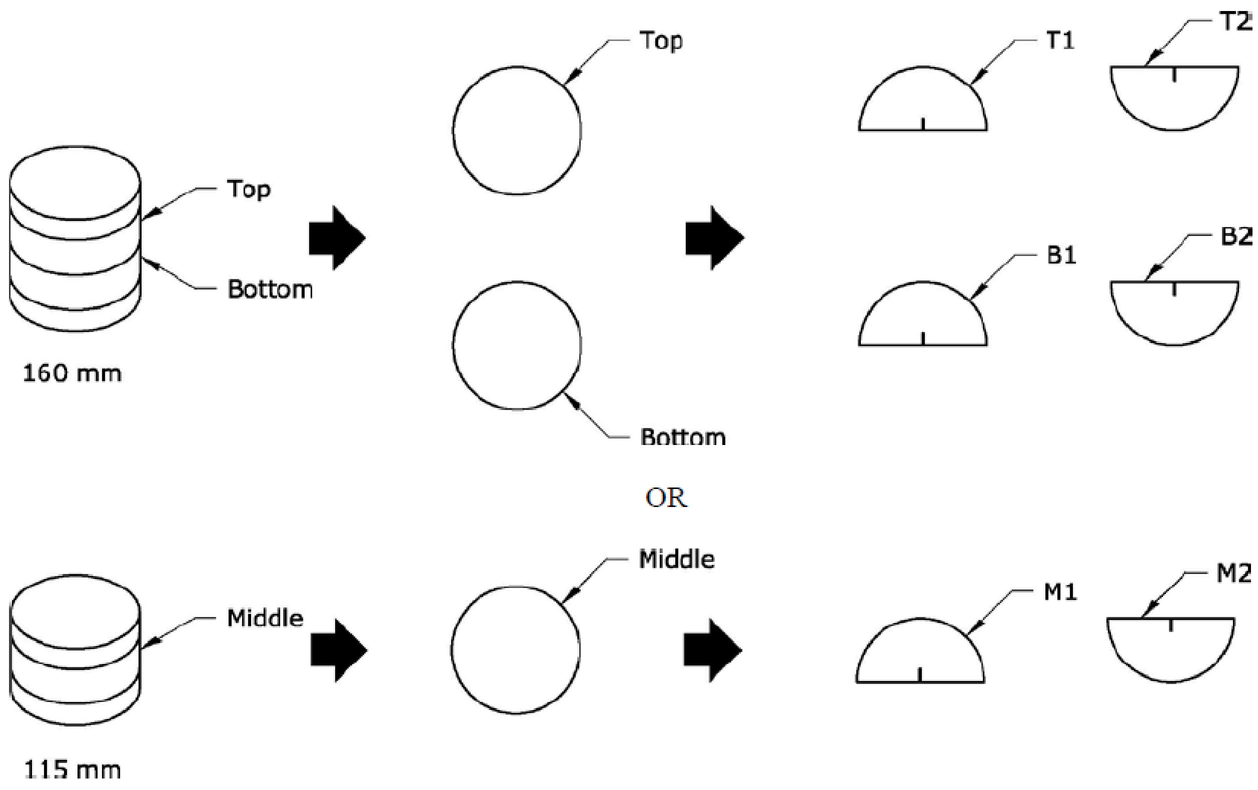


Figure 4— Specimen preparation from 160 mm or 115 mm SGC specimens

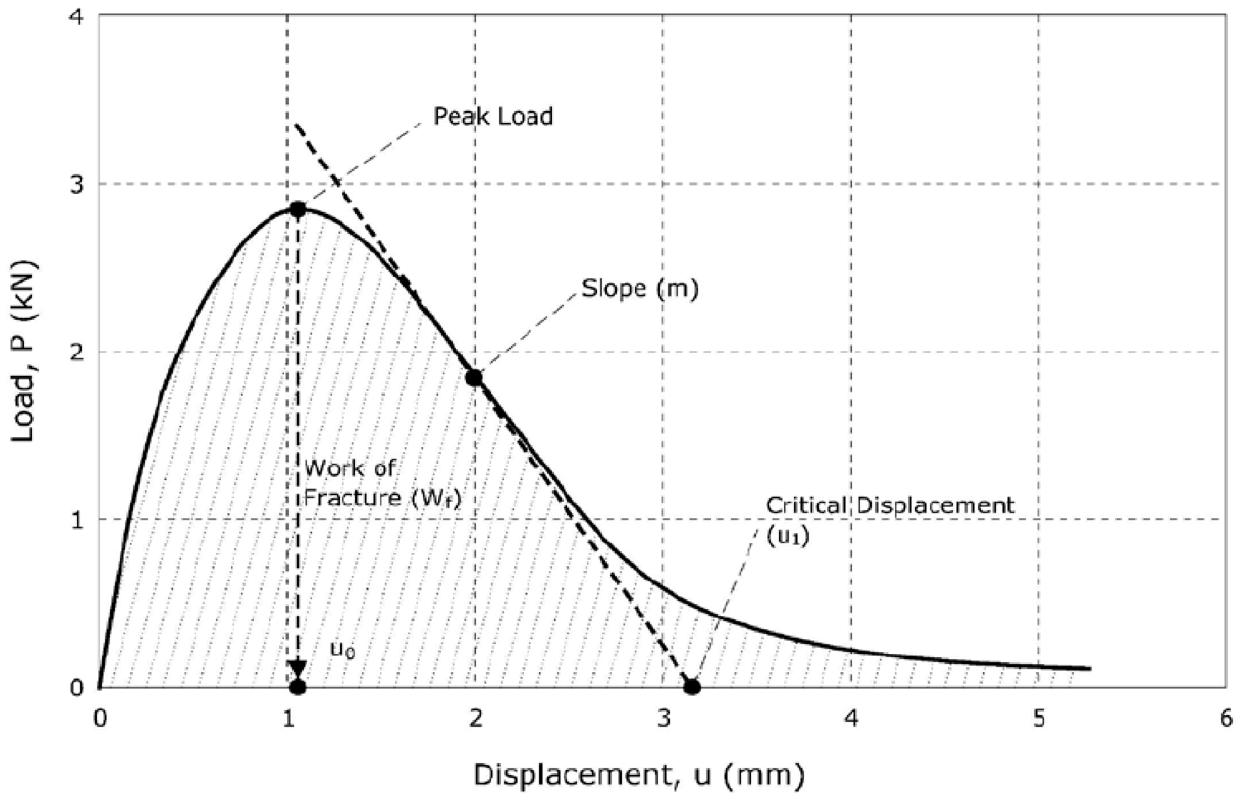
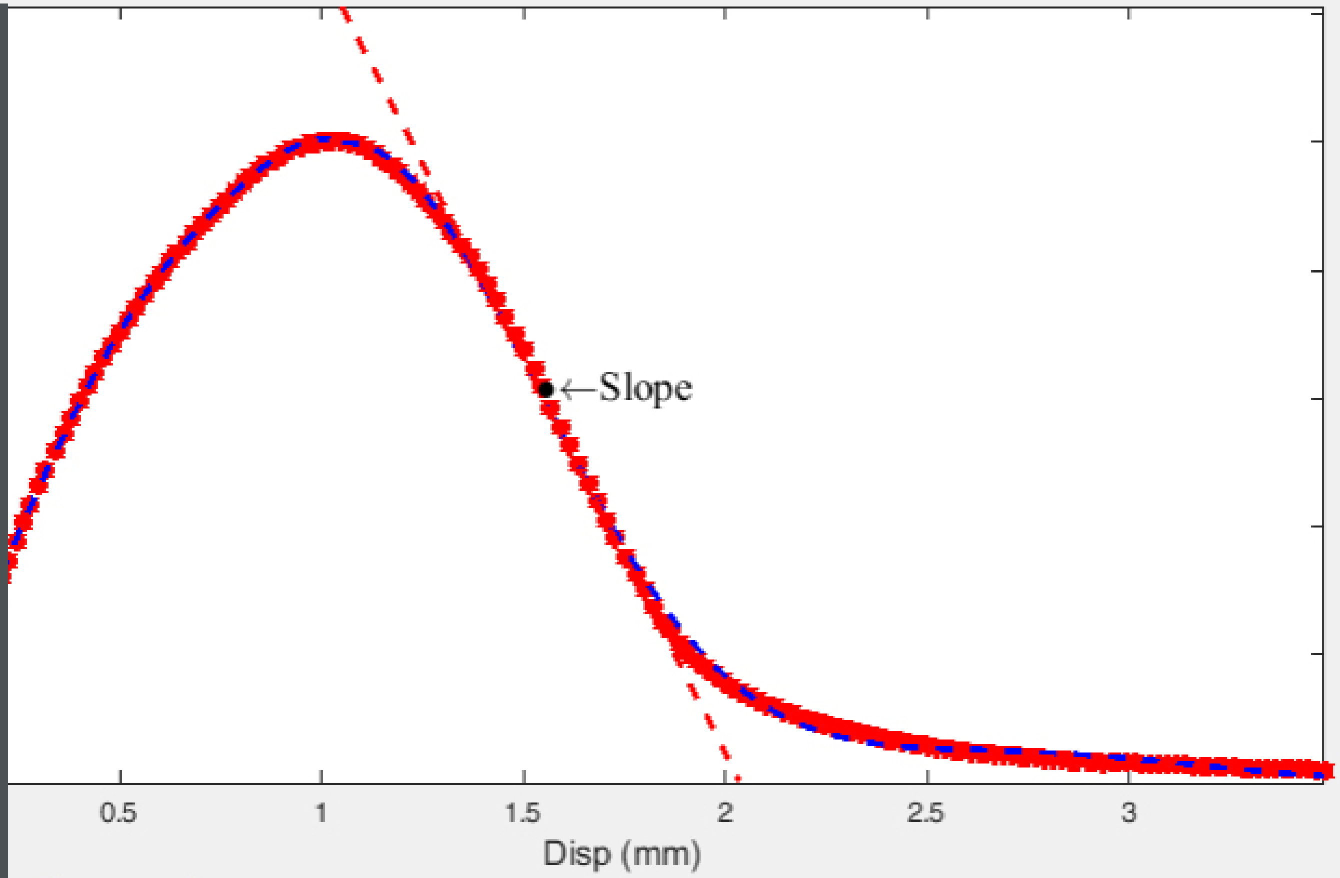


Figure 5—Recorded load (P) versus load line displacement (u) curve

Flexibility Index (IFIT) AASHTO TP124

Upload Data

Project ID: info Specimen ID: 2
Thickness: 50.1 mm Ligament: 56.5 mm



Summary Output

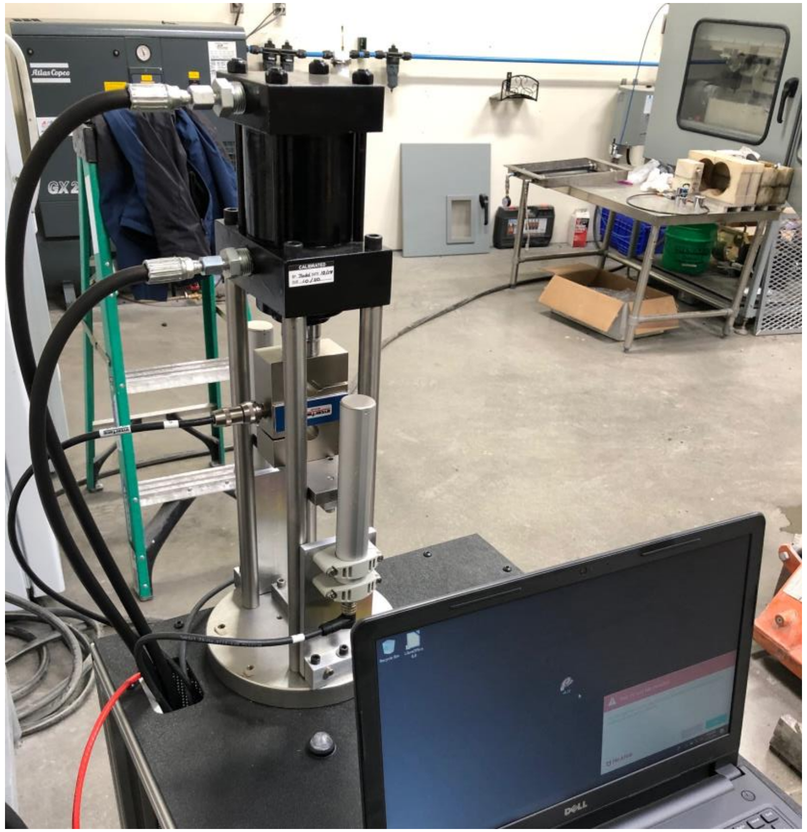
Fracture Energy (J/m2)	2389.28
Strength (Psi)	101.82
Slope	-6.13
Flexibility Index	3.9

Flexibility Index (IFIT) Illinois Test Procedure 405

3.0 Flexibility Index Testing. The FI testing will be completed in accordance with Illinois Test Procedure 405 dated 01/01/16 available at http://www.modot.org/business/contractor_resources/forms.htm In lieu of the FI, the Ideal CT criteria may be substituted using the limits shown below. The Ideal CT shall be completed in accordance with ASTM D8225 and at a test temperature of 25 F when used.

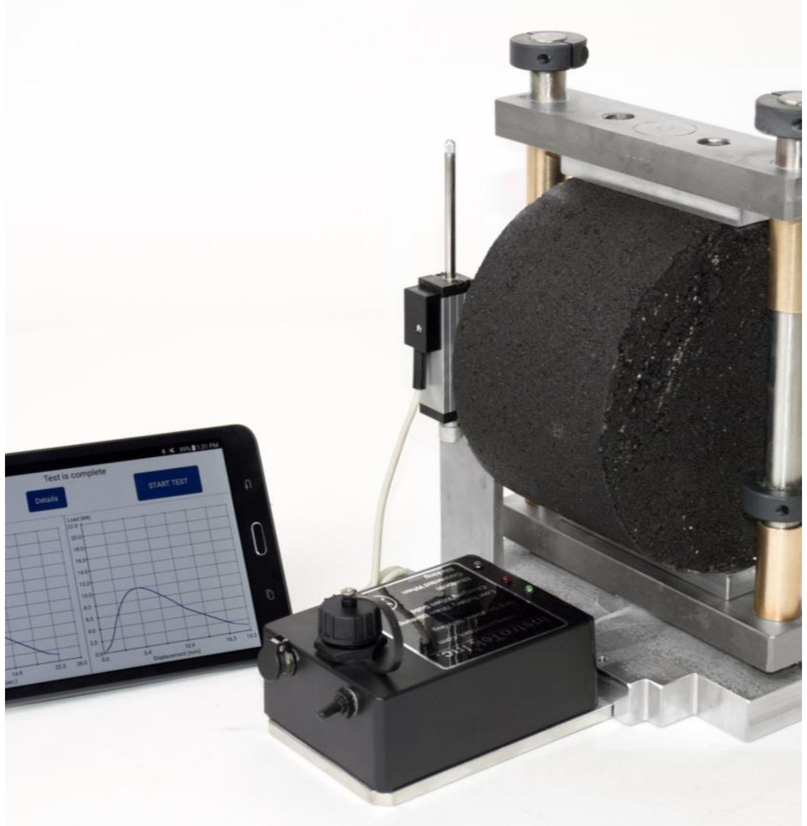
FLEXIBILITY INDEX	Ideal CT	Percent of Contract Price
NMAS <190	NMAS <190	
< 2.0	< 32	98%
2.0 – 3.9	32 – 60	100%
4.0 – 7.9	60 - 97	102%
>8.0	> 97	103%

MoDOT Superpave Performance Testing and Increased Density - JSP



Testquip-IDEAL CT Index

Pine Instrument Model 850



Instrotek Smart Jig

IDEAL CT (Crack Testing) Index (ASTM D 8225)

IDEAL CT-INDEX (ASTM D 8225)

- Crack Testing using IDEAL CT-Index Test
  - Methodology Developed by Texas Transportation Institute @ Texas A & M

Development of an IDEAL Cracking Test for Asphalt Mix Design and QC/QA

Fujie Zhou*[a], Soohyok Im[a], Lijun Sun[b], and Tom Scullion[a]

[a]*Texas A&M Transportation Institute, College Station, Tx, 77843*
[b]*Tongji University, Shanghai, China, 200092.*

Designation: D8225 – 19

Standard Test Method for
Determination of Cracking Tolerance Index of Asphalt Mixture Using the Indirect Tensile Cracking Test at Intermediate Temperature[1]

IDEAL CT-INDEX (ASTM D 8225)

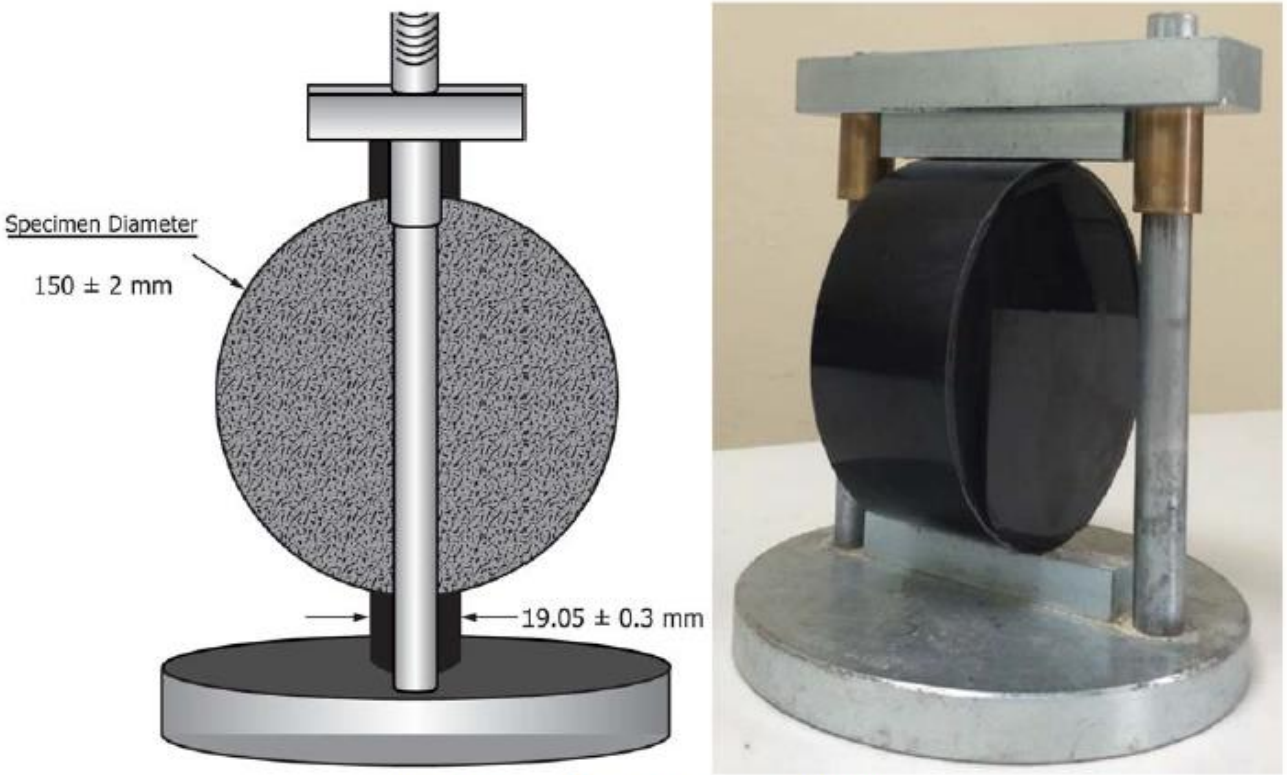


FIG. 2 Traditional Indirect Tension Test Fixture

IDEAL CT-INDEX (ASTM D 8225)

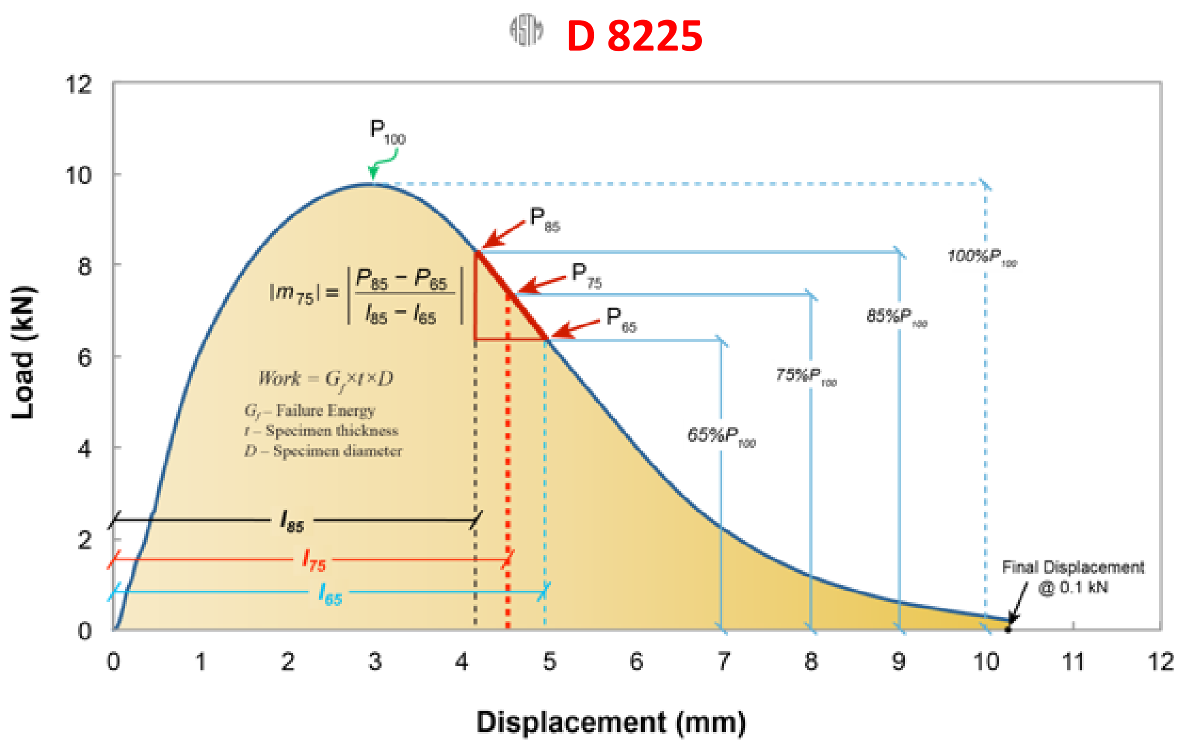


FIG. 1 Recorded load (P) versus load-line displacement (l) curve

IDEAL CT-INDEX (ASTM D 8225)

IDEAL CT-INDEX

- Based on ASTM D8225:
  - *Specimen Size* – For the mixes with a nominal maximum aggregate size (NMAS) of 19 mm or smaller, the specimens are 150 mm in diameter by 62 ±1 mm thick; For the mixes with a NMAS of 25 mm or larger, specimens are 150 mm in diameter by 95 ±1 mm thick. All specimens are prepared without cutting or trimming.
- *Aging* – Laboratory-compacted test specimens shall be properly conditioned before the compaction.
  - Note 2: For laboratory-mixed and laboratory-compacted (LMLC) mixes, specimens should be short-term conditioned for 4 hours according to AASHTO R 30 for Mixture Mechanical Property Testing. For plant-mixed and laboratory-compacted mixes (PMLC), specimens may be compacted after reheating the mix to its compaction temperature. **(4 hours @ 135°C)**

NCAT Report 18-04, PHASE VI (2015-2017) NCAT TEST TRACK FINDINGS

"NCAT researchers first evaluated several options for aging of the mixtures and established a loose mix aging protocol of eight hours at 135°C (275°F) to simulate in-situ aging of a surface layer to point where cracking typically begins (*2*)." (NCAT report 18-04,pg.44)

"The laboratory aging protocol used for this study to simulate in-service aging is eight hours at 135°C in a loose mix state. NCAT refers to this protocol as "critically aged" and it represents 70,000 cumulative degree days (CDD) of in-situ aging, which is when top down cracking typically occurs in surface layers (*26*)." (NCAT report 18-04,pg.58)

IDEAL CT-INDEX (ASTM D 8225)

- *Air Void Content* – Prepare a minimum of three specimens at the target air void content ± 0.5%..
  - Note 3 – The specimen air voids can be calculated using Test Methods D3203/D3203M. The typical air void target for highway pavements is 7.0%. Other target air voids can be used, but specimens with significantly different air voids (larger than ± 0.5%) are not comparable.
- NOTE: Bluegrass Testing Lab makes six specimens per test group, data is examined for average and standard deviation. Any data points beyond ± 1 standard deviation is removed from the data analysis group, new average calculated. The extra specimens beyond the minimum of three specified allow for data cleanup if needed.
- ASTM E178 for statistical outliers

IDEAL CT-INDEX (ASTM D 8225)

- Specimens are conditioned 2 hrs.±10 min. in environmental chamber or water bath at target intermediate performance grade temperature (PG IT)
  - PG IT= [(PG High Temperature+PG Low Temperature)/2]+4
  - Example:
    - PG 64-22=[(64-22)/2]+4=25°C
    - PG 76-22=31°C **<u>(NOTE if PG IT > 25°C, use 25°C)</u>**
    - PG 64-28=22°C
  - Typical target (PG IT) temperature is 25°C (77°F)
- KYTC Method (Determination of Asphalt Mixture Cracking Resistance (KYCT) of Bituminous Mixtures) specifies (after specimen fabrication) 1 hour at room temperature and 1 hour in 77°F water bath prior to breaking

IDEAL CT-INDEX (ASTM D 8225)

- Apply load to specimen in LLD control at a rate of 50 ± 2.0 mm/min. Stop the test when the load drops below 100 N. During the testing, record the time, load, and displacement at a minimum sampling rate: 40 data points per second.
- **NOTE1:** The precontact load that was in the original draft was found to be insignificant and was removed in this subsequent version
- **NOTE2:** The data acquisition rate of the Pine 850 break press was reported to be 20 data points per second. TTI (Texas A&M) validated many series of test results sent and reviewed to confirm data rate of 20 per second is sufficient. REASON FOR 40 per second is roadway cores that may break quickly and getting enough data for a smooth curve maybe difficult.
- **NOTE3:** Pine 850 has been reported to not be in the 50 ± 2.0 mm/min range.

1 V1.03 850 - IDEAL-CT

2 **Pine 850 IDEAL-CT Workbook**

3 Show/Hide Formula Rows

4 **Project ID**

14	I_{75}	4.833	I_{75}	4.961	I_{75}	5.182	I_{75}		I_{75}		I_{75}		I_{75}		I_{75}	
18	m_{75}	3.858	m_{75}	3.283	m_{75}	3.243	m_{75}		m_{75}		m_{75}		m_{75}		m_{75}	
19	W_f	90.72	W_f	96.00	W_f	90.12	W_f		W_f		W_f		W_f		W_f	
20	G_f	9755.4	G_f	10322.5	G_f	9689.8	G_f		G_f		G_f		G_f		G_f	
21	CT_{Index}	81.5	CT_{Index}	104.0	CT_{Index}	103.2	CT_{Index}		CT_{Index}		CT_{Index}		CT_{Index}		CT_{Index}	
22	Sample 1 ID	1	Sample 2 ID	2	Sample 3 ID	3	Sample 4 ID		Sample 5 ID		Sample 6 ID		Sample 7 ID		Sample 8 ID	
23	Temp [C]	77.0	Temp [C]	77.0	Temp [C]	77.0	Temp [C]		Temp [C]		Temp [C]		Temp [C]		Temp [C]	
24	Air Voids	6.80%	Air Voids	7.20%	Air Voids	7.10%	Air Voids		Air Voids		Air Voids		Air Voids		Air Voids	
25	Diameter	150.0	Diameter	150.0	Diameter	150.0	Diameter		Diameter		Diameter		Diameter		Diameter	
26	Thickness	62.0	Thickness	62.0	Thickness	62.0	Thickness		Thickness		Thickness		Thickness		Thickness	
27	Flow/Stability Data															
28	1		2		3											
29	2.895	16.398	2.888	16.071	3.301	16.225										
30	Flow (mm)	Stability (kN)	Flow	Stability	Flow	Stability	Flow	Stability	Flow	Stability	Flow	Stability	Flow	Stability	Flow	Stability
31	0.000	0.1770	0.000	0.1286	0.000	0.0525										
32	0.081	1.1272	0.088	0.7842	0.103	0.0734										
33	0.096	1.3425	0.103	0.9533	0.121	0.0850										
34	0.110	1.5604	0.119	1.1116	0.140	0.0836										
35	0.124	1.7713	0.134	1.2909	0.159	0.0658										
36	0.138	1.9835	0.149	1.4746	0.178	0.0641										
37	0.147	2.1939	0.157	1.6792	0.190	0.0778										
38	0.161	2.4123	0.171	1.8856	0.208	0.0970										
39	0.175	2.6316	0.186	2.0960	0.227	0.0988										
40	0.189	2.8589	0.200	2.2917	0.245	0.1001										

Typical Pine 850 Data File (w/digital recorder)

28	1	
29	2.895	16.398
30	Flow (mm)	Stability (kN)
31	0.000	0.1770
32	0.081	1.1272
33	0.096	1.3425
34	0.110	1.5604
35	0.124	1.7713
36	0.138	1.9835
37	0.147	2.1939
38	0.161	2.4123
39	0.175	2.6316
40	0.189	2.8589

649	10.942	0.1294
650	10.960	0.1130
651	10.979	0.1068
652	10.998	0.1099
653	11.016	0.1085
654	11.035	0.1085
655	11.048	0.0890

Pine 850 Test Press Data Acquisition Rate

- The platen has a nominal speed of 2 inches per minute. Call that 50 mm per minute. Your test has (655-31=624) 624 data points in 12.455 mm.
- 11.048 mm x (1 minute / 50 mm) x (60 seconds / min) = 13.26 seconds of runtime.
- 624 data points / 13.26 seconds = 47 points per second, or 47 Hz
- Now, the platen speed is our old spec without frame deflection considered. I can’t imagine that accounts for more than half the flow. It looks like we’re already getting 40 pts per second

ASTM X XXXX

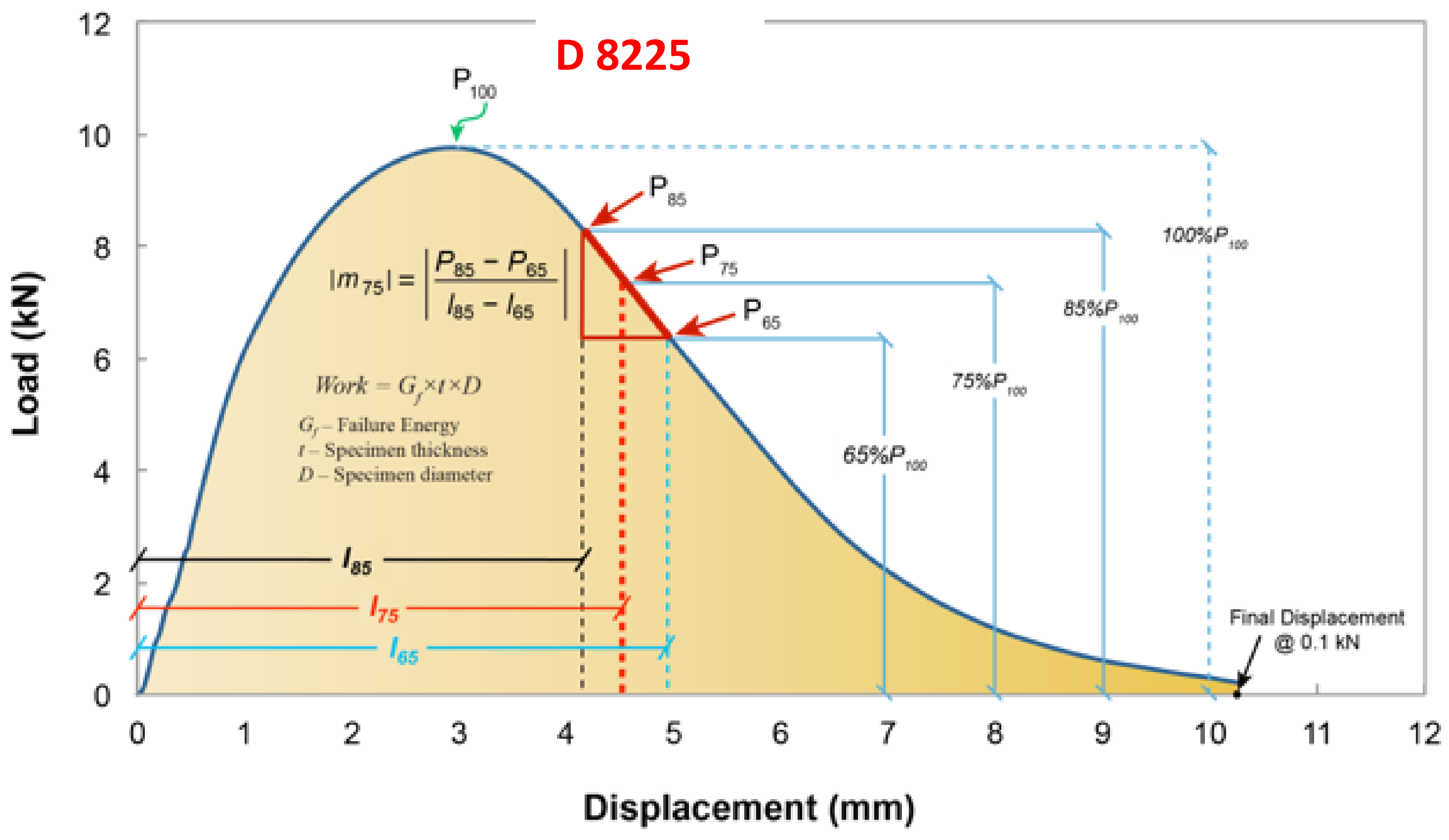


FIG. 1 Recorded load (*P*) versus load-line displacement (*l*) curve

IDEAL CT-INDEX (ASTM D 8225)

IDEAL CT-INDEX (ASTM D 8225)

- CT-Index value is calculated as:
  - The work of failure (W_f) is calculated as the area under the load vs. LLD curve (see Fig. 1) through the quadrangle rule provided in Eq 2:
- $W_f = \sum_{i=1}^{n-1}\left((l_{i+1} - l_i) \times P_i + \frac{1}{2} \times (l_{i+1} - l_i) \times (P_{i+1} - P_i)\right)$ (2)
- where:
- P_i = applied load (kN) at the *i* load step application,
- P_{i+1} = applied load (kN) at the *i+1* load step application,
- l_i = LLD (mm) at the *i* step, and
- l_{i+1} = LLD (mm) at the *i+1* step.

IDEAL CT-INDEX (ASTM D 8225)

- AND…
  - Failure energy (G_f) is calculated by dividing the work of failure (the area under the load versus the average LLD curve; see Fig. 1) by the cross-sectional area of the specimen (the product of the diameter and thickness of the specimen):
- $G_f = \frac{W_f}{D \times t} \times 10^6$
- where:
- G_f = failure energy (Joules/m^2)
- W_f = work of failure (Joules)
- D = specimen diameter (mm)
- t = specimen thickness (mm)

IDEAL CT-INDEX (ASTM D 8225)

- **AND FINALLY…..**
- Post-peak slope (m_{75}) is the slope of tangential zone around the 75 % peak load point after the peak, see Fig. 1.
- Deformation tolerance (l_{75}) is the displacement at 75 % the peak load after the peak.
- Cracking test index (CT_{Index}) is calculated from the parameters obtained using the load-displacement curve, as listed below:
- $CT_{Index} = \frac{t}{62} \times \frac{l_{75}}{D} \times \frac{G_f}{|m_{75}|} \times 10^6$
- where:
- CT_{Index} = Cracking Test Index
- G_f = failure energy (Joules/m^2)
- $|m_{75}|$ = absolute value of the post-peak slope m_{75} (N/m)
- l_{75} = displacement at 75 % the peak load after the peak (mm)
- D = specimen diameter (mm)
- t = specimen thickness (mm)
- Note 7 – $\frac{t}{62}$ is a correction factor for specimen thickness. 10^6 is a scale factor

IDEAL CT-INDEX (ASTM D 8225)

D 8225

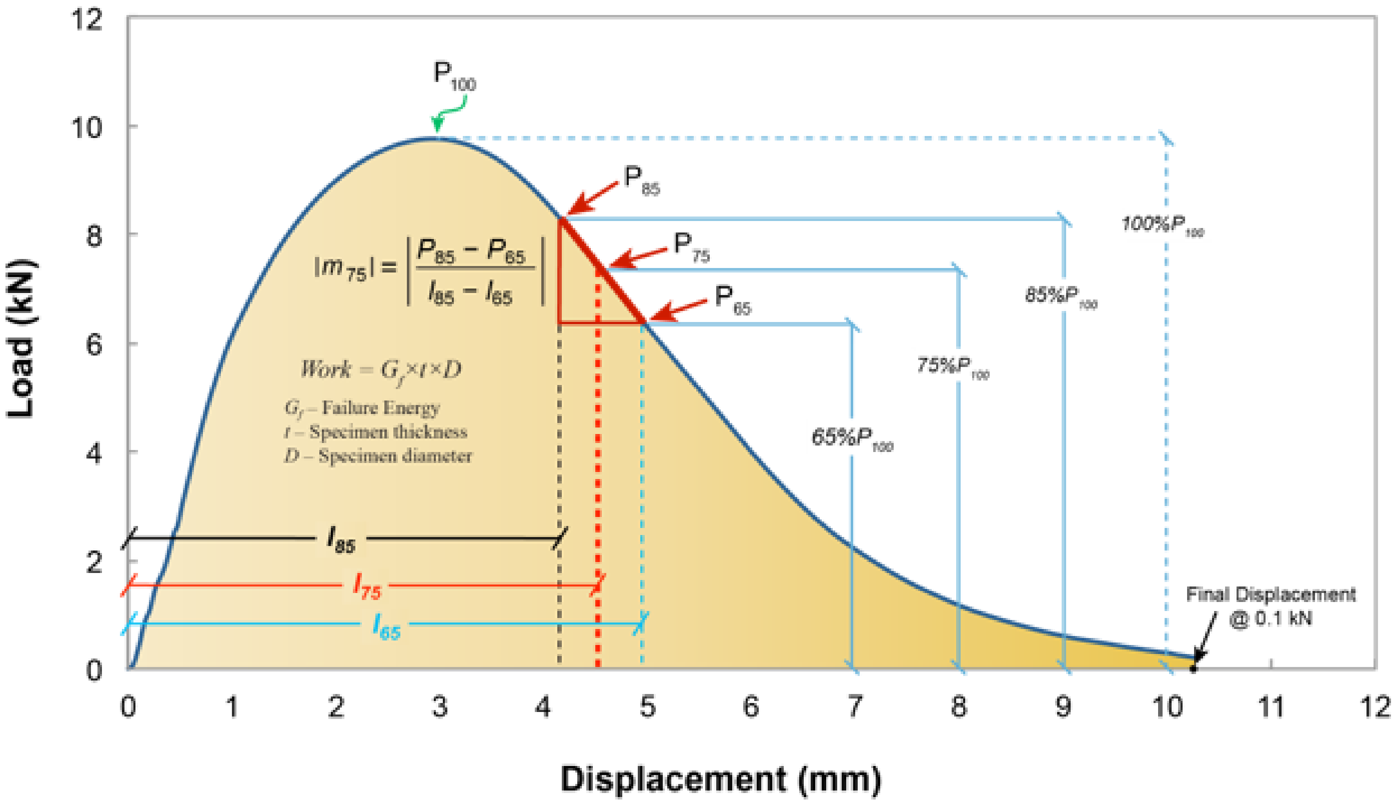


FIG. 1 Recorded load (*P*) versus load-line displacement (*l*) curve

$$CT_{Index} = \frac{t}{62} \times \frac{l_{75}}{D} \times \frac{G_f}{|m_{75}|} \times 10^6$$

Initial IDEAL CT INDEX Field Data

Pine 850 Break Press equipped with digital recorder and Version 1.02 software

File Home Insert Page Layout Formulas Data Review View Help Acrobat Pine 850 Tell me what you want to do Share Comments

SECURITY WARNING Some active content has been disabled. Click for more details. Enable Content

Series7_N...

V1.02 850TD

PINE test equipment

Ending Serial Communication...

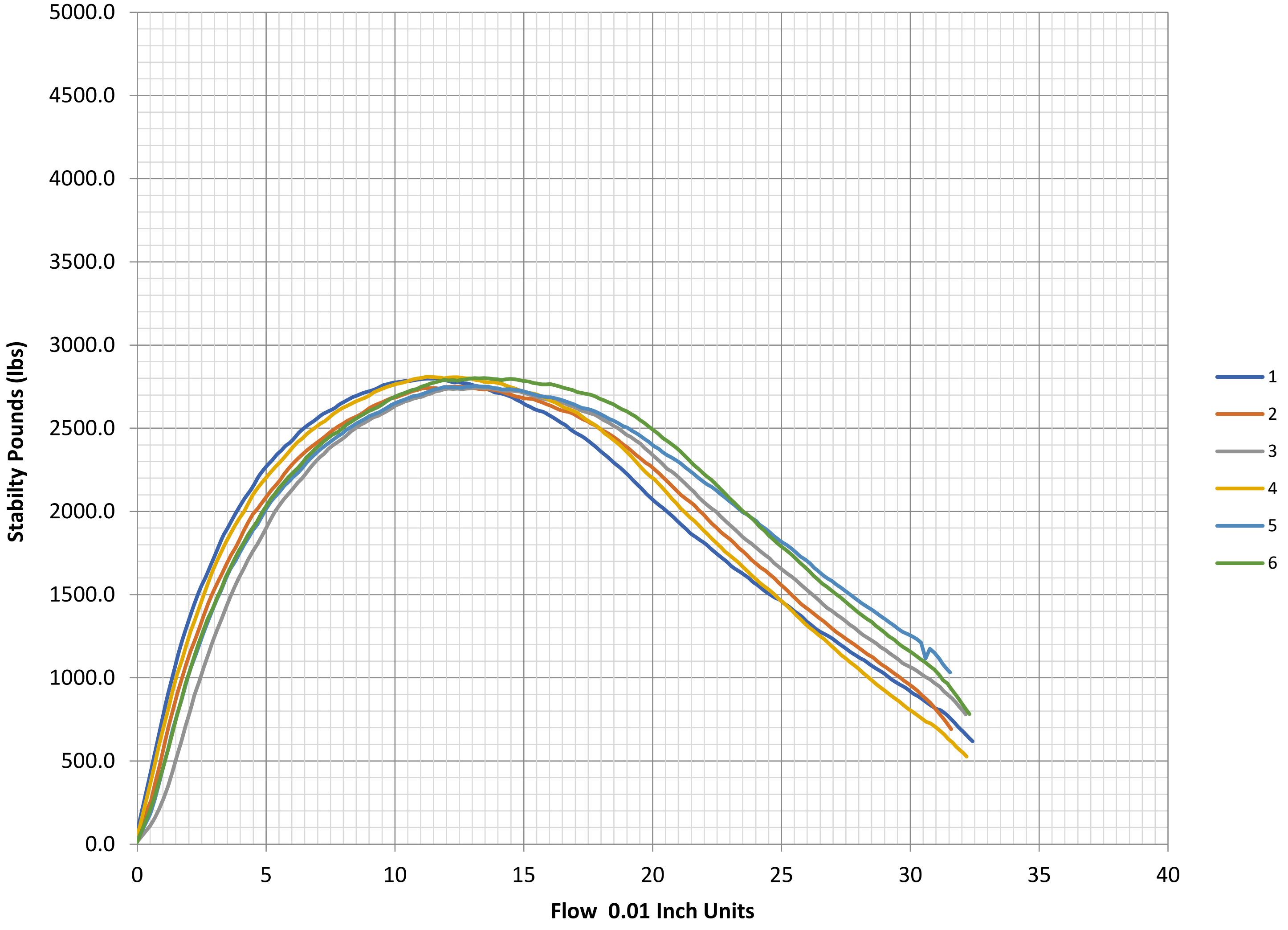
Pine 850TD Workbook

Units: English Metric Mixed

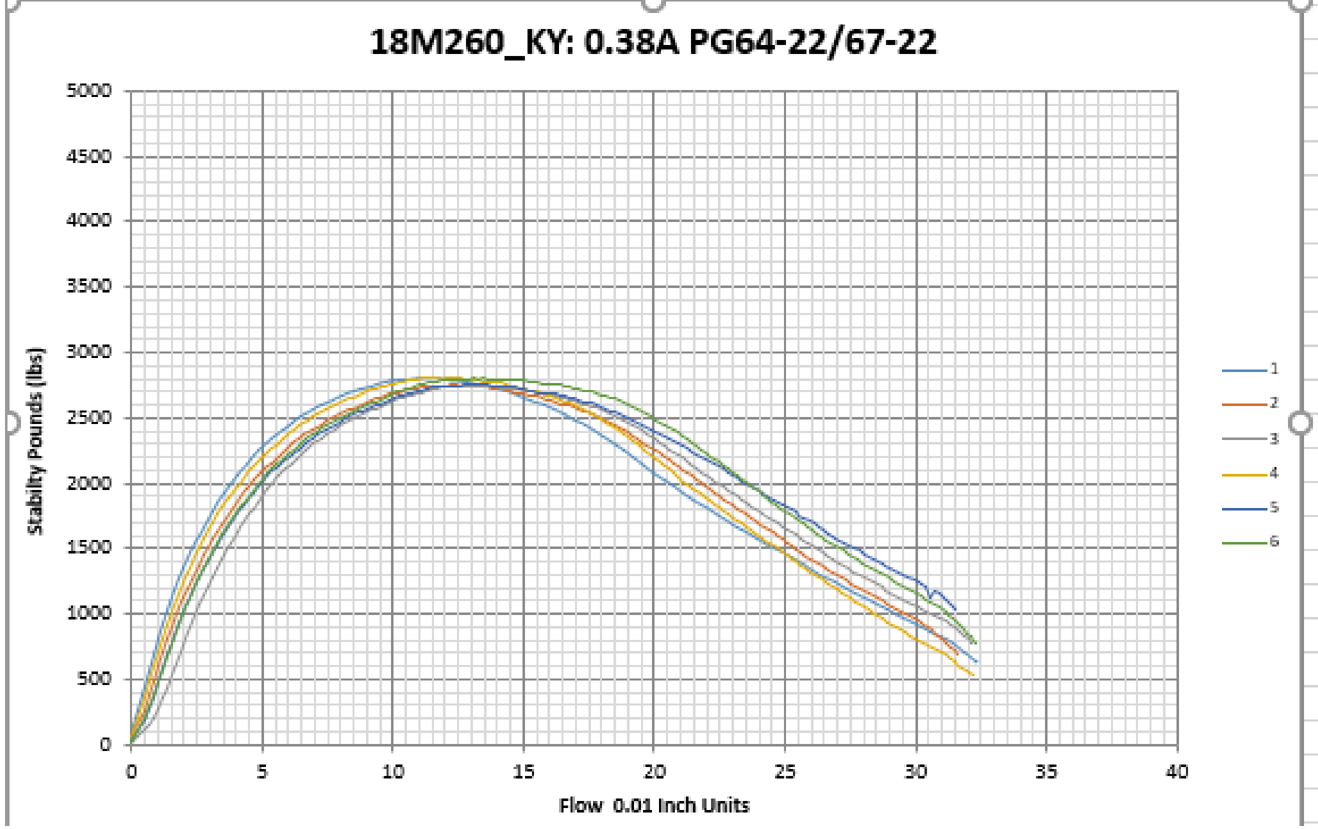
Marshall Test Press Flow/Stability Data

Specimen 1		Specimen 2		Specimen 3		Specimen 4		Specimen 5		Specimen 6		Specimen 7		Specimen 8	
1		2		3		4		5		6					
Flow	Stability	Flow	Stability	Flow	Stability	Flow	Stability	Flow	Stability	Flow	Stability	Flow	Stability	Flow	Stability
0.00	76.2	0.00	61.0	0.00	13.5	0.00	41.7	0.00	21.3	0.00	11.6				
0.51	423.5	0.54	263.5	0.51	111.6	0.51	364.1	0.51	182.2	0.51	207.4				
1.10	839.0	0.71	374.0	0.68	157.6	0.68	481.7	0.68	269.8	0.68	288.1				
1.27	947.5	0.88	480.8	0.85	211.0	0.85	597.6	0.85	367.2	0.85	377.7				
1.44	1048.2	1.05	595.3	1.03	275.8	1.03	707.1	1.03	473.4	1.03	472.8				
1.61	1151.0	1.22	706.8	1.20	352.1	1.22	817.9	1.22	580.5	1.20	570.8				
1.78	1240.7	1.39	808.9	1.37	436.0	1.37	919.7	1.37	684.6	1.37	670.9				
1.95	1321.8	1.56	906.7	1.54	526.0	1.54	1015.7	1.56	782.7	1.54	769.3				

18M260_KY: 0.38A PG64-22/67-22

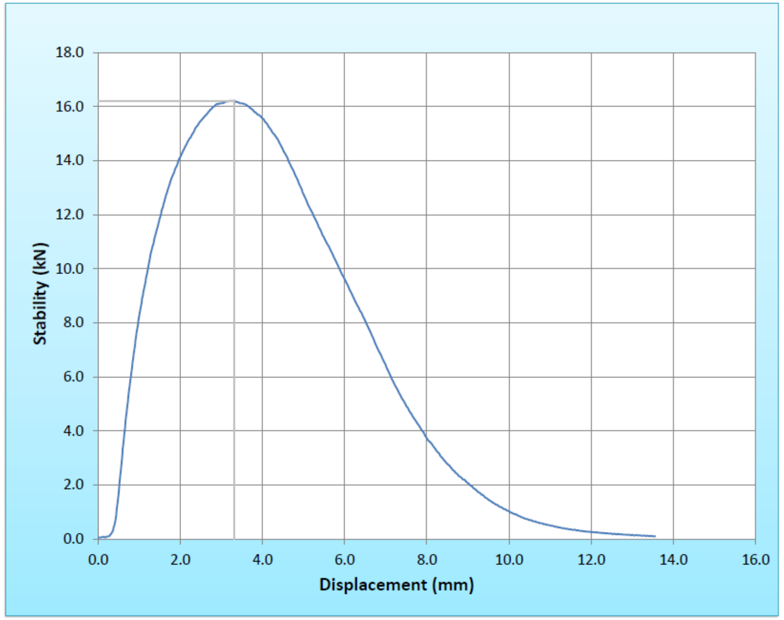


18M260_KY	0.38A PG64-22/PG67-22 (4Hr cure, 1Hr Air + 1 Hr Bath)					
Specimen #	Mix ID	Mix Type	CT Index	Standard Deviation	Coefficient of Variance	Air Voids%
1	18M260_KY	PG64-22/67-22	88.2	8.98	9.59	7.2
2	18M260_KY	PG64-22/67-22	91.4			7.1
3	18M260_KY	PG64-22/67-22	91.6			7.2
4	18M260_KY	PG64-22/67-22	82.4			7.0
5	18M260_KY	PG64-22/67-22	111.2			7.4
6	18M260_KY	PG64-22/67-22	96.9			7.4
	Average		93.62	SD = 84.64, 102.60		7.2
	Ave. within SD		92.03			



PINE test equipment

IDEAL-CT Report



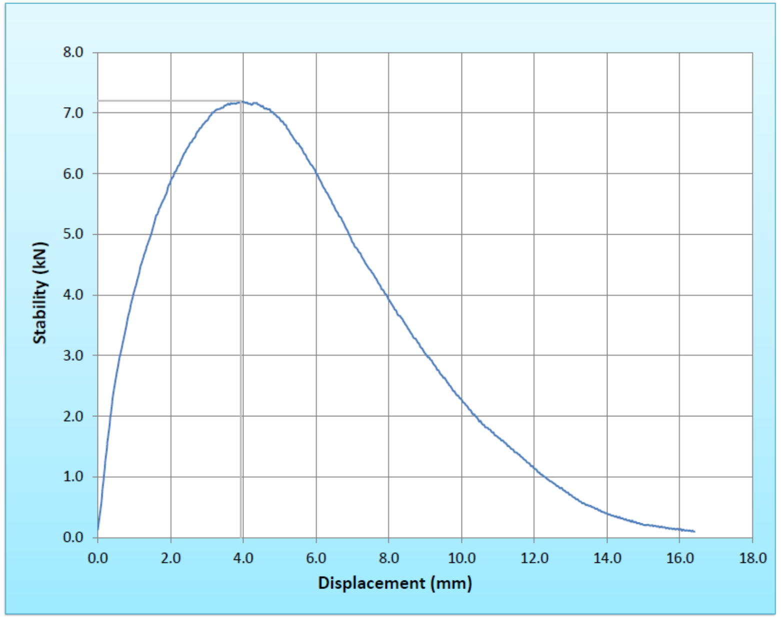
Inputs	
Date/Time	11/26/2019
Project ID	0
Sample ID	3
Asphalt Mixture Type	SURF 0.38D PG76-22
Test Temperature (°C)	77
Air Voids	7.10 %
Gmm	2.484
% AC	5.8 %
Specimen Prep Method and Aging Condition	4Hr oven cure/1Hr air/1Hr
Specimen Thickness (mm)	62.0 mm
Specimen Diameter (mm)	150.0 mm

Outputs	
Peak Stability	16.225 kN
Displacement at Peak Stability	3.30 mm
Deformation Tolerance (l_{75})	5.18 mm
Post-Peak Slope (m_{75})	3.24 N/m^2
Failure Energy (G_f)	9689.8 $Joules/m^2$
Work of Failure (W_f)	90.12 Joules
Cracking Tolerance (CT_{Index})	103.215

Notes:

PINE test equipment

IDEAL-CT Report



Inputs	
Date/Time	11/27/2019
Project ID	0
Sample ID	3
Asphalt Mixture Type	CL3 0.38 PG58-28
Test Temperature (°C)	77.0
Air Voids	740.00 %
Gmm	2.485
% AC	5.8 %
Specimen Prep Method and Aging Condition	4 Hr/1Hr air/1Hr bath
Specimen Thickness (mm)	62.0 mm
Specimen Diameter (mm)	150.0 mm

Outputs	
Peak Stability	7.202 kN
Displacement at Peak Stability	3.92 mm
Deformation Tolerance (l_{75})	6.54 mm
Post-Peak Slope (m_{75})	1.12 N/m^2
Failure Energy (G_f)	6005.2 $Joules/m^2$
Work of Failure (W_f)	55.85 Joules
Cracking Tolerance (CT_{Index})	234.527

Notes:

Performance Testing in Kentucky

- After the presentation made in early August 2018, discussions had with KYTC for a trial project to evaluate IDEAL CT-Index Testing and Hamburg Loaded Wheel Testing
- Selected was Jefferson County, Hurstbourne Lane
- Louisville Paving Company was successful bidder on this job earlier in the year
- Original mainline surface was a KYTC CL 3 ASPH SURF 0.38 A PG 64-22
- Change order issued. Going from a 4.0 % air voids to a 3.5 % air voids pick increased asphalt content from 5.6 % to 5.8 %

KYTC Mixpack Data from Hurstbourne Lane

AGG. TYPE	G_{sb}	%
Dolomite #8's Class A	2.66	28
Dolomite Sand Class A	2.72	10
LSS (Washed)	2.68	24
Natural Sand	2.60	10
LS #11's (Unwashed)	2.69	13
Fine RAP	2.70	15

CL 3 ASPH SURF 0.38A PG 64-22

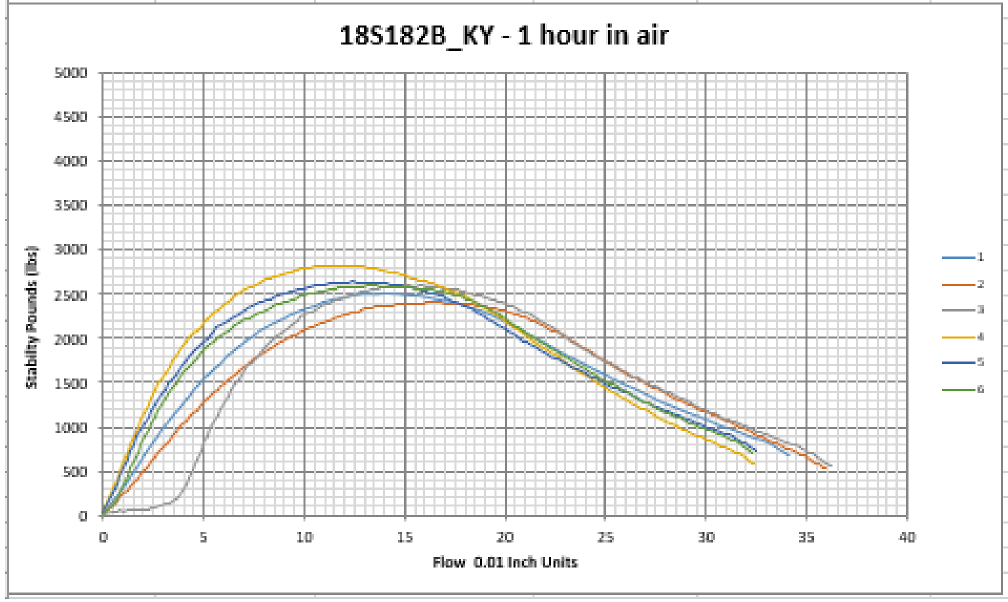
Sieve	JMF
2 "	100
1 1/2 "	100
1 "	100
3/4 "	100
1/2 "	100
3/8 "	97
1/4 "	N / A
#4	76
#8	45
#16	28
#30	19
#50	12
#100	9
#200	7.5

% VFA	**77.4**	73 - 76
% VMA	**15.7**	15.0 (minimum)
D/A Ratio	**1.4**	0.8 - 1.6
% G_{mm} @ $N_{initial}$	**87.0**	89.0 (maximum)
% G_{mm} @ N_{max}	**97.3**	98.0 (maximum)
% Air Voids	**3.5**	4.0
Unit Weight (lb/ft^3)	**149.4**	
% AC	**5.8**	

Hurstbourne Lane

- CL 3 ASPH SURF 0.38A PG 64-22
- CT Index Value at Mix Design Phase = 95.3

	0.38A PG64-2	4HR oven Cure, 1 hour in air				
Specimen #	Mix ID	Mix Type	CT Index	Standard Deviation	Coefficient of Variance	Air Voids
1	18S182B_KY_4hr	0.38A PG64-22	99.6	7.62	8.20	7.2
2	18S182B_KY_4hr	0.38A PG64-22	103.7			7.5
3	18S182B_KY_4hr	0.38A PG64-22	96.6			7.4
4	18S182B_KY_4hr	0.38A PG64-22	84.3			7.3
5	18S182B_KY_4hr	0.38A PG64-22	89.6			7.2
6	18S182B_KY_4hr	0.38A PG64-22	83.5			7.4
		Average	92.9	(average=95.3 ± 1 std.deviation)		



Bluegrass Testing

Performance Testing in Kentucky

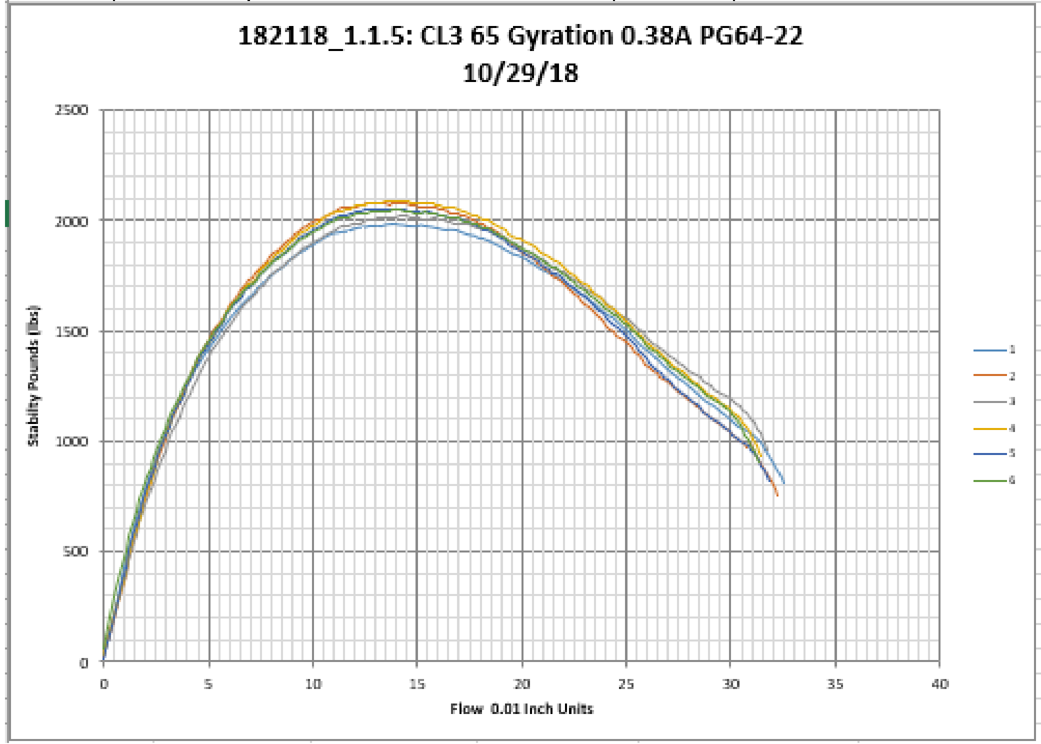
- Hurstbourne Lane responsibilities:
  - STILL CONDUCT NORMALLY REQUIRED VOLUMETRIC TESTING REQUIRED PER SUBLOT (1000 Tons)
  - ADDITIONALLY: PERFORM KYCT CT-Index Testing per 500-ton sublots
  - Job had 8000 tons, so after first 500 tons for setup, intentions to run 15 sublots for CT Index Testing (making 6 specimens for CT Index per 500 tons)
  - Perform Hamburg Loaded Wheel Testing

Hurstbourne Lane Sublot #1.1.5 Test Data

- CT Index = 126
- Mix production/placement time not more than 50 minutes

	182118_1.1.5	10/29/18 mix production		65 gyration, 0.38A w/PG 64-22		500-1000 tons
Specimen #	Mix ID	Mix Type	CT Index	Standard Deviation	Coefficient of Variance	% Air Voids
1	182118_1.1.5	0.38A PG64-22	133.3	8.33	6.64	6.9
2	182118_1.1.5	0.38A PG64-22	117.9			6.8
3	182118_1.1.5	0.38A PG64-22	137.5			6.8
4	182118_1.1.5	0.38A PG64-22	122.4			6.7
5	182118_1.1.5	0.38A PG64-22	113.8			6.6
6	182118_1.1.5	0.38A PG64-22	128.2			6.8
		average=	125.52			6.8

NOTE: Mix production was just ahead of loadout, estimated time from production to placement is 35-50 minutes



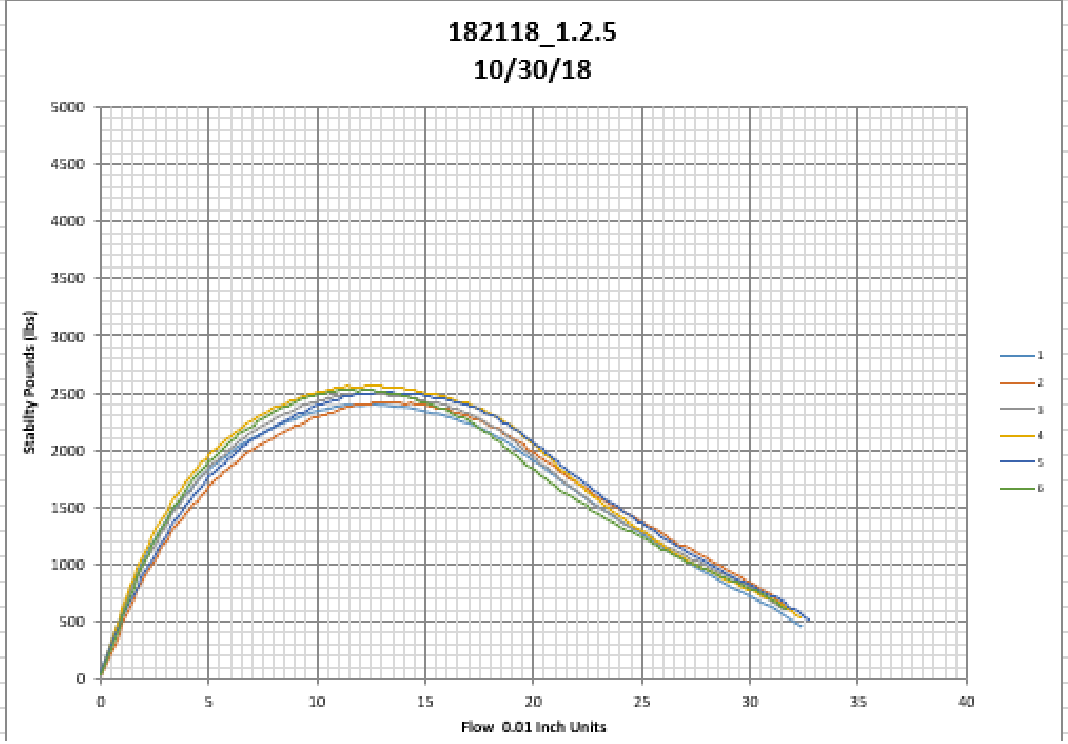
Bluegrass Testing

Hurstbourne Lane Sublot #1.2.5 Test Data

- CT Index = 76
- Mix production/placement time somewhere up to 5 hours

	182118_1.2.5	10/30/18 mix production		65 gyration, 0.38A PG 64-22		1500-2000 tons
						% Air
Specimen #	Mix ID	Mix Type	CT Index	Standard Deviation	Coefficient of Variance	Voids
1	182118_1.2.5	0.38A(65 gyr)	83.3	6.23	8.19	7.1
2	182118_1.2.5	0.38A(65 gyr)	83.7			7.1
3	182118_1.2.5	0.38A(65 gyr)	70.6			7.1
4	182118_1.2.5	0.38A(65 gyr)	71			6.7
5	182118_1.2.5	0.38A(65 gyr)	79.1			7.1
6	182118_1.2.5	0.38A(65 gyr)	68.5			7.1
		average=	76.03			7.0

NOTE: Mix production was many hours ahead of loadout, estimated time from production to placement is up to 5.0 hours



Bluegrass Testing

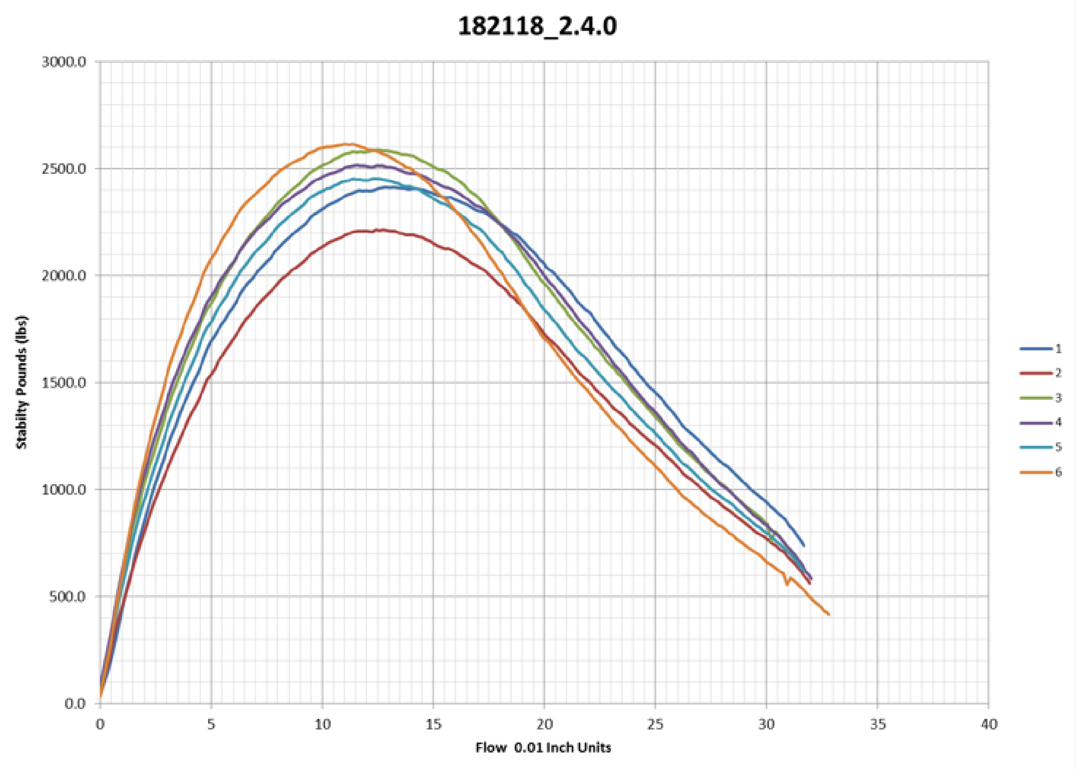
Hurstbourne Lane Sublot #2.4.0 Test Data

- CT Index = 81
- Mix production/placement time not more than 1.5 hours
- AC Tested 0.4% LOW

182118_2.4.0	11/8/18 Mix Production		65 Gyration 0.38A PG64-22		7000-7500 tons	
Specimen #	Mix ID	Mix Type	CT Index	Standard Deviation	Coefficient of Variance	%Air Voids
1	182118_2.4.0	0.38A PG64-22	92.1	7.59	9.38	7.3
2	182118_2.4.0	0.38A PG64-22	82.2			7.5
3	182118_2.4.0	0.38A PG64-22	79.9			7.5
4	182118_2.4.0	0.38A PG64-22	86.2			7.3
5	182118_2.4.0	0.38A PG64-22	77.4			7.3
6	182118_2.4.0	0.38A PG64-22	67.6			6.9
		Average	80.9			7.3

NOTE1: Mix sample had low AC%. Target 5.8 %, Tested 5.4 %.

NOTE2: Mix produced estimated 45 min. to 1 hr before load out.



Hurtbourne Lane Laboratory Design Phase

- IDEAL CT Index = 95.3

HURSTBOURNE LANE CT INDEX VALUES FOR ALL SUBLOTS

SUBLOT#	CT-INDEX	DATE	Time to Placement	NOTES:
1.1.5	125.52	10/29/18	50 min.	
1.2.0	117.65	10/29/18	50 min.	
1.2.5	76.03	10/30/18	5 hrs.	
1.3.0	102.35	11/2/18	50 min.	
1.3.5	103.90	11/2/18	50 min.	
1.4.0	78.20	11/2/18	50 min.	%AC low 0.4 %
1.4.5	96.90	11/6/18	1.5 hrs.	
2.1.0	113.70	11/6/18	1.5 hrs.	
2.1.5	92.50	11/6/18	3.0 hrs.	
2.2.0	102.90	11/6/18	3.0 hrs.	
2.2.5	103.90	11/7/18	3.0 hrs.	
2.3.0	109.80	11/7/18	3.0 hrs.	
2.3.5	112.40	11/7/18	1.5 hrs.	
2.4.0	80.90	11/8/18	1.5 hrs.	%AC low 0.4 %

OBSERVATIONS:

(1) AVERAGE CT INDEX FOR ALL SUBLOTS= 101.19

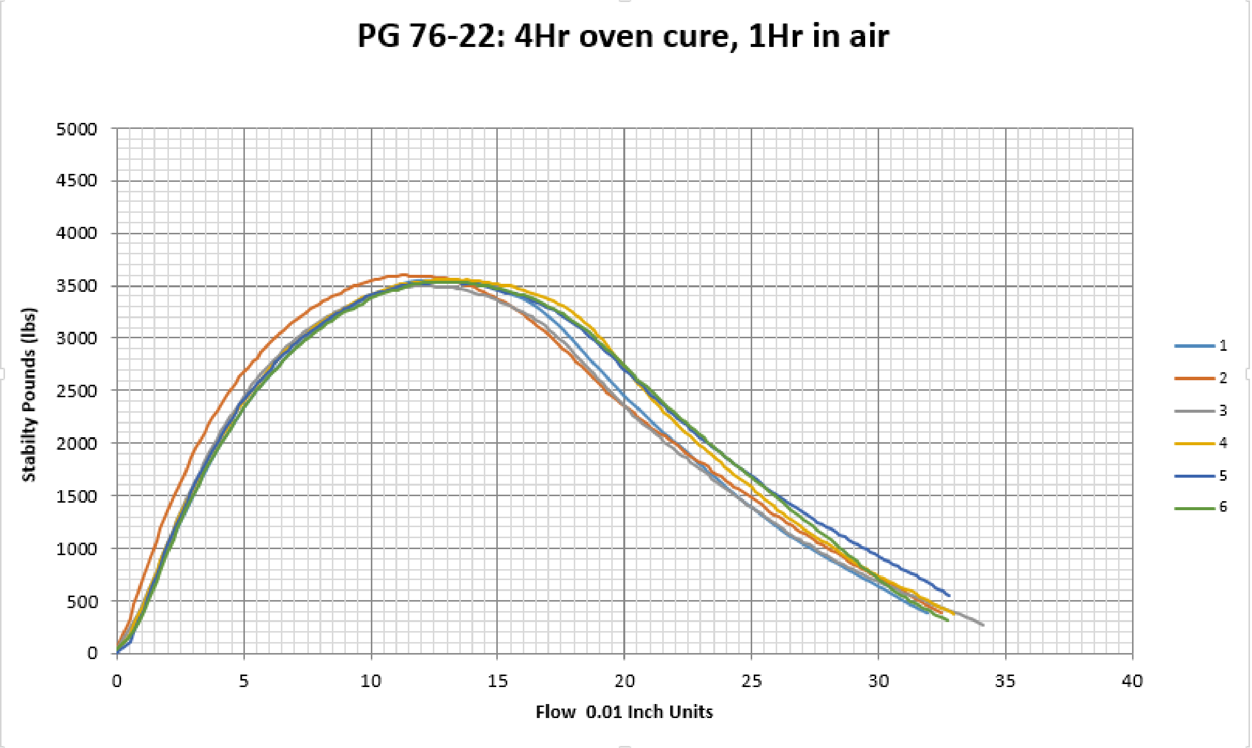
(2) LOW CT-INDEX VALUE= 76.03

(3) HIGH CT-INDEX VALUE= 125.52

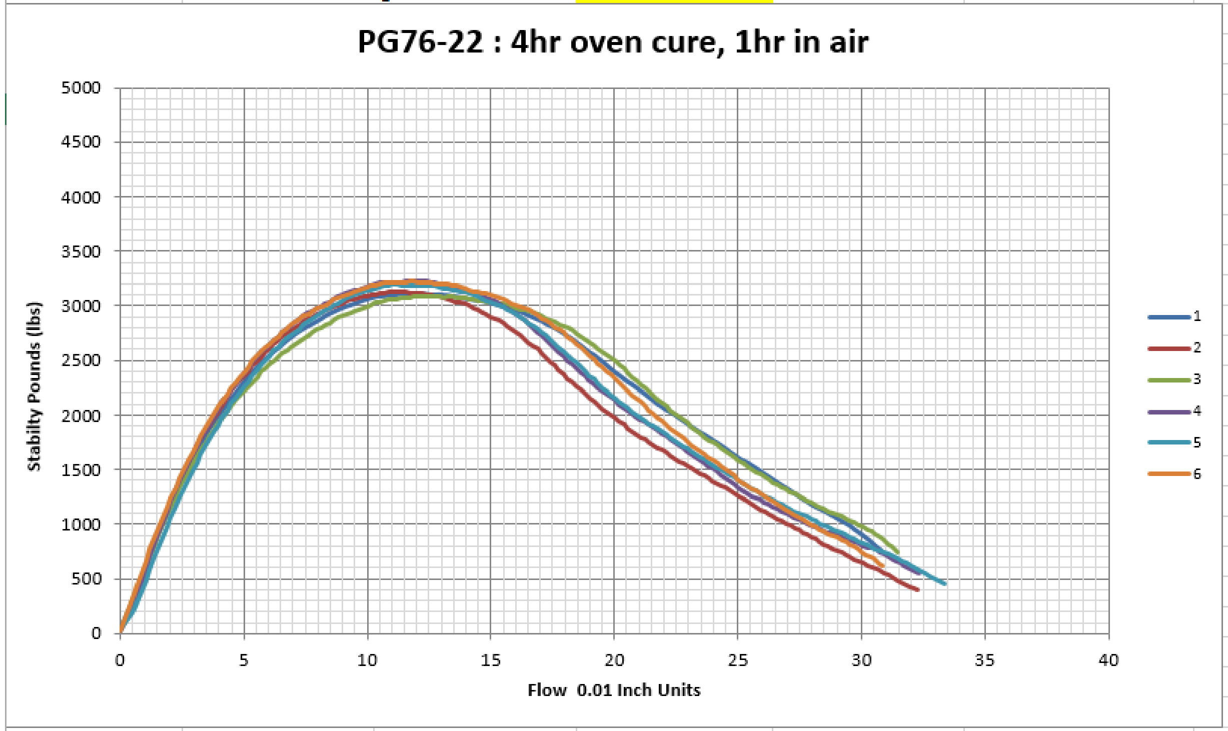
(4) FACTORS AFFECTING CT-INDEX VALUES:

- STORAGE TIME
-% AGGREGATE ABSORPTION CHARACTERISTICS

	0.38A PG76-22		4Hr oven cure, 1 Hr in air			
Specimen #	Mix ID	Mix Type	CT Index	Standard Deviation	Coefficient of Variance	Air Voids%
1	PG76-22: 1Hr	0.38A PG76-22	55.9	5.88	9.52	7.2
2	PG76-22: 1Hr	0.38A PG76-22	62.8			6.8
3	PG76-22: 1Hr	0.38A PG76-22	57.1			7.1
4	PG76-22: 1Hr	0.38A PG76-22	56.1			7.0
5	PG76-22: 1Hr	0.38A PG76-22	67.8			6.8
6	PG76-22: 1Hr	0.38A PG76-22	70.8			7.0
	Average		61.75	Limits of 1 std. dev.= 55.87, 67.63		
	Average within 1 std. dev.		57.98			



	0.38A PG76-22		4hr oven cure, 1 hr in air			
Specimen #	Mix ID	Mix Type	CT Index	Standard Deviation	Coefficient of Variance	Air Voids%
1	PG76-22: 1HR	0.38A PG76-22	78	6.39	9.65	6.6
2	PG76-22: 1HR	0.38A PG76-22	58.5			6.6
3	PG76-22: 1HR	0.38A PG76-22	70.7			6.6
4	PG76-22: 1HR	0.38A PG76-22	61.9			6.4
5	PG76-22: 1HR	0.38A PG76-22	64.2			6.8
6	PG76-22: 1HR	0.38A PG76-22	64.2			6.3
		Average	66.25	Limits of 1 std. dev. = 59.86, 72.64		
	Average within 1 std. dev.		65.25			



High % RAP Surface and Performance Testing

DATE:	5/28/2019	
PROJECT NAME:	60 % RAP w/REJUVENATOR and PG 58-28 vs 25 % RAP w/PG 64-22	
MIX TYPE:	9.5mm Surface	
	Mix A (50 % Binder Replacement)	Mix B (21 % Binder Replaceent)
MIXTURE COMBINATION TEST PROPERTY	60 % RAP w/0.10 % (wt. of mix) REJUVENATOR and PG 58-28	25 % RAP w/ PG 64-22
IDEAL CT-INDEX	126.3	108.2
Disk-Shaped Compact Tension (DCT), Fracture Energy (J/m²)	**389.7** (@ -12 C)	**362.3** (@ -12 C)
Hamburg Loaded Wheel Rut Depth (mm):	3.4 mm @ 10,000 cycles	4.1mm @ 10,000 cycles

VDOT/VTRC Project Initiation

BALANCED MIX DESIGN FOR ASPHALT MIXTURES: HIGH RAP FIELD TRIALS

This project will document and assess field trials constructed under VDOT's Special Provision for High RAP Content Surface Mixtures Designed Using Performance Criteria.

The trials will also provide a resource to begin evaluating the impact of performance specifications on the long-term performance of pavement surfaces.

Solicitation for Volunteer Participation

- This project depended heavily on the Asphalt Producer/Contractor's willingness to volunteer
- A number of contractor's are interested in participating
- In 2019 two took part:
  - Superior Paving Corp.
  - Boxley Asphalt

Superior Paving Corp.
Bull Run

Superior designed mixes for two separate plants. Both high RAP and standard RAP mixes were produced with a number of combinations at the Bull Run facility.

Superior Paving Corp. – Bull Run

Superior Paving Corp. - Bull Run				
MIX	IDEAL-CT		CANTABRO	
SM-9.5A	Design	Production	Design	Production
30% RAP Control	60.5	127.6	7.1	4.4
40% RAP Ingevity	104.6	110.7	4.0	3.4
40% RAP PG58-28	73.5	99.9	4.0	4.1
40% RAP PG64-22	111.0	99.1	5.5	4.6
30% RAP PG58-28	157.4	183.2	3.5	3.2

- All trials at this facility easily passed the specification criteria.
- Criteria settings were even questioned.

Taylor County Airport

- Project had been paved 4 years previously
- Extensive microcracking throughout the mat
- Airport Board wanted most crack-resistant pavement they could get
  - Reflective Crack Interlayer (RCI) on top of cracked mat
    - 7.5% PG 64-22 s/Aramid Fibers
    - Design IDEAL-CT INDEX of 133.9
  - Mainline 9.5mm Surface on top of RCI
    - 6.4% PG 64-22 w/Aramid Fibers
    - Design IDEAL-CT INDEX of 130.0
    - Production IDEAL-CT INDEX of 189-220
  - Helipad Surface
    - Mainline 9.5mm surface with 6.4% PG 76-22 and Aramid Fibers
    - Production IDEAL-CT INDEX of 367

Factors Affecting IDEAL-CT Index Values

Asphalt Binder Grade

- Softer binder grades may yield higher CT-Index
- Binders modified w/rejuvenator have shown higher IDEAL CT-Index values

Asphalt Binder Content

- % Total Binder (% ac variations below optimum will decrease CT-Index)
- % Effective Binder Content
  - longer mix storage times(production) with absorptive aggregate have shown lower CT-Index values [% EFFECTIVE BINDER CONTENT LOWER]
  - Mix storage times(production) much less than lab design phase(4 hours) have shown higher CT-Index values. {% EFFECTIVE BINDER CONTENT HIGHER]

Factors Affecting IDEAL-CT Index Values

- Mix Modifiers
  - Chemical additives have shown ability to increase CT-Index
  - Aramid fibers have shown ability to increase CT-Index

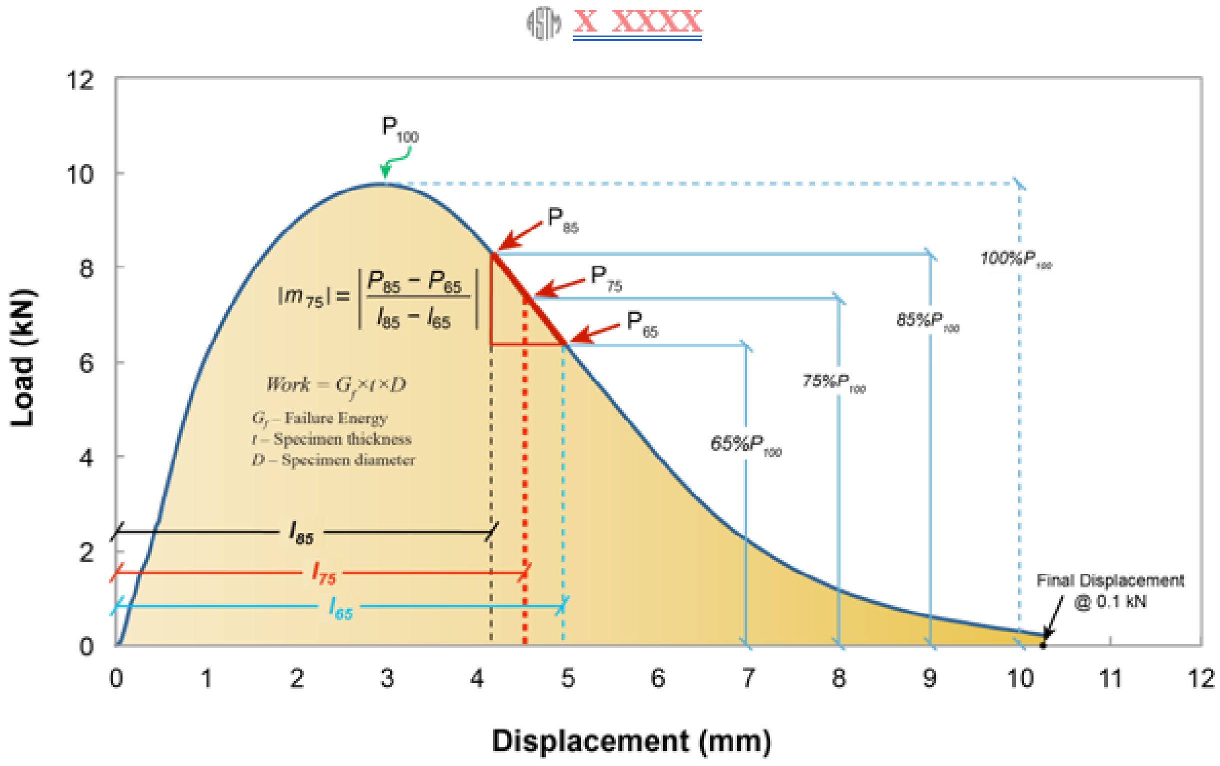


FIG. 1 Recorded load (*P*) versus load-line displacement (*l*) curve

$$CT_{Index} = \frac{t}{62} \times \frac{l_{75}}{D} \times \frac{G_f}{|m_{75}|} \times 10^6$$

Bluegrass Testing

Cantabro Test

Test Procedure for

CANTABRO LOSS

TxDOT Designation: Tex-245-F

Effective Date: July 2019

Cantabro Test Background

- Originally designed to assess durability in Open-Graded Friction Course mixes (TXDOT Test Method 245).
  - TxDOT 245, Section 1.2,"The percent of weight loss (Cantabro Loss) is an indication of.....durability and relates to the quantity and quality of the asphalt binder."

Standard Method of Test for Abrasion Loss of Asphalt Mixture Specimens

AASHTO Designation: TP 108-14 (2018)[1]

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

AASHTO

5. SIGNIFICANCE AND USE

5.1. The test method described is used to indirectly assess the cohesion, bonding, and effects of traffic abrasion on asphalt mixtures. This procedure is typically used in the PFC mix design process. Test specimens may be either laboratory-compacted specimens or sampled from pavements.

Contabro Test Background

- Uses a Los Angeles Abrasion Drum without steel charges to degrade asphalt specimens
- Provisional AASHTO Test Method-TP108-14(2018)
  - Standard Method of Test for Abrasion Loss of Asphalt Mixture Specimens
  - TP108,Section 5

Los Angeles Abrasion Device

Cantabro Specimen Preparation

- Gyratory specimens
  - 3 replicates
  - Compacted to Ndes at compaction temperature
  - Height 115 ± 5 mm
  - Weight: Use weight on JMF
  - Measure air voids
    - Report
  - Field Cores
    - Informational purposes only
    - Measure air voids

Cantabro Specimen Preparation

- Dry specimen
  - Use dry(air) weight from bulk specific gravity determination
- Temperature
  - 77 ± 2°F
  - Should remain at this temperature for 4 hours before testing

Cantabro Testing Parameters

- Place individual Cantabro specimen in LA machine drum without steel charges
- Turn drum at 30 to 33 rpm for 300 revolutions
- Record initial and final specimen weight
- Mass Loss[Cantabro Loss](%)= [(Winitial-Wfinal)/Winitial]x100

VIRGINIA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION FOR
HIGH RECLAIMED ASPHALT PAVEMENT (RAP) CONTENT SURFACE MIXTURES DESIGNED USING PERFORMANCE CRITERIA

I. Description

These Specifications cover the requirements and materials used to produce High RAP Content Surface Mixtures, containing 40% RAP and higher, designed using Performance Criteria. High RAP Content Surface Mixtures shall be designed, produced, and placed as required by this Special Provision and Sections 211 and 315 of the Specifications. High RAP Content Surface Mixtures consist of a combination of coarse aggregate, fine aggregate, RAP, and liquid asphalt binder mechanically mixed in a plant to produce a stable asphalt concrete paving mixture.

Cantabro Percent (%) Loss Specification

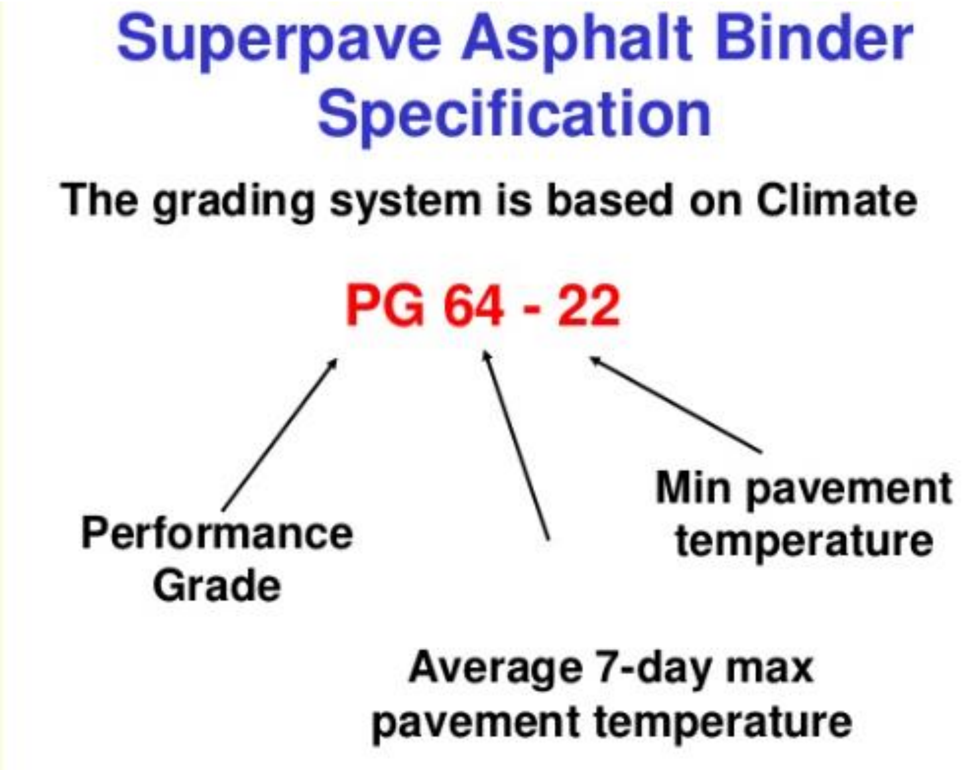
Cantabro Test

- Additional Guidelines
    - Specimens
        - Gyratory Pill
            - Compacted to N_{design} at 50 gyrations
            - Diameter = 150mm
            - Height = 115 ±5mm
            - Volumetric pills
        - Minimum 3 replicates
    - Test Temperature of 25 ± 1° C
    - 300 Revolutions
    - Mass Loss ≤7.5%

Asphalt Binder Testing

Balanced Mix Design

Asphalt Binder Terminology



- What would a continuous grade of PG 67.1-24.1 Mean?

Performance Grades

Original

- ≥230 °C — **Flash Point**
- ≤ 3 Pa-s @ 135 °C — **Rotational Viscosity**
- ≥ 1.00 kPa — **DSR G*/sin δ** (Dynamic Shear Rheometer)

(Rolling Thin Film Oven) RTFO, Mass Change ≤ 1.00%

- ≥ 2.20 kPa — **DSR G*/sin δ** (Dynamic Shear Rheometer)

(Pressure Aging Vessel) PAV

- 20 hours, 2.10 MPa
- ≤ 5000 kPa — **DSR G*sin δ** (Dynamic Shear Rheometer) — Intermediate Temp. = [(Max. + Min.)/2] + 4
- S ≤ 300 MPa, m ≥ 0.300 — **BBR S (creep stiffness) & m-value** (Bending Beam Rheometer)
- If BBR m-value ≥ 0.300 and creep stiffness is between 300 and 600, the Direct Tension failure strain requirement can be used in lieu of the creep stiffness requirement.
- ε_f ≥ 1.00% — **DTT** (Direct Tension Tester)

Max. Design Temp.	PG 46		
Min. Design Temp.	-34	-40	-46
Original DSR G*/sin δ ≥ 1.00 kPa	46		
RTFO DSR G*/sin δ ≥ 2.20 kPa	46		
PAV 20 hours, 2.10 MPa	90		
PAV DSR G*sin δ ≤ 5000 kPa	10	7	4
BBR S ≤ 300 MPa, m ≥ 0.300	-24	-30	-36
DTT ε_f ≥ 1.00%	-24	-30	-36

Max. Design Temp.	PG 52						
Min. Design Temp.	-10	-16	-22	-28	-34	-40	-46
Original DSR G*/sin δ ≥ 1.00 kPa	52						
RTFO DSR G*/sin δ ≥ 2.20 kPa	52						
PAV 20 hours, 2.10 MPa	90						
PAV DSR G*sin δ ≤ 5000 kPa	25	22	19	16	13	10	7
BBR S ≤ 300 MPa, m ≥ 0.300	0	-6	-12	-18	-24	-30	-36
DTT ε_f ≥ 1.00%	0	-6	-12	-18	-24	-30	-36

Max. Design Temp.	PG 58				
Min. Design Temp.	-16	-22	-28	-34	-40
Original DSR G*/sin δ ≥ 1.00 kPa	58				
RTFO DSR G*/sin δ ≥ 2.20 kPa	58				
PAV 20 hours, 2.10 MPa	100				
PAV DSR G*sin δ ≤ 5000 kPa	25	22	19	16	13
BBR S ≤ 300 MPa, m ≥ 0.300	-6	-12	-18	-24	-30
DTT ε_f ≥ 1.00%	-6	-12	-18	-24	-30

Max. Design Temp.	PG 64					
Min. Design Temp.	-10	-16	-22	-28	-34	-40
Original DSR G*/sin δ ≥ 1.00 kPa	64					
RTFO DSR G*/sin δ ≥ 2.20 kPa	64					
PAV 20 hours, 2.10 MPa	100					
PAV DSR G*sin δ ≤ 5000 kPa	31	28	25	22	19	16
BBR S ≤ 300 MPa, m ≥ 0.300	0	-6	-12	-18	-24	-30
DTT ε_f ≥ 1.00%	0	-6	-12	-18	-24	-30

Max. Design Temp.	PG 70					
Min. Design Temp.	-10	-16	-22	-28	-34	-40
Original DSR G*/sin δ ≥ 1.00 kPa	70					
RTFO DSR G*/sin δ ≥ 2.20 kPa	70					
PAV 20 hours, 2.10 MPa	100(110)					
PAV DSR G*sin δ ≤ 5000 kPa	34	31	28	25	22	19
BBR S ≤ 300 MPa, m ≥ 0.300	0	-6	-12	-18	-24	-30
DTT ε_f ≥ 1.00%	0	-6	-12	-18	-24	-30

Max. Design Temp.	PG 76				
Min. Design Temp.	-10	-16	-22	-28	-34
Original DSR G*/sin δ ≥ 1.00 kPa	76				
RTFO DSR G*/sin δ ≥ 2.20 kPa	76				
PAV 20 hours, 2.10 MPa	100(110)				
PAV DSR G*sin δ ≤ 5000 kPa	37	34	31	28	25
BBR S ≤ 300 MPa, m ≥ 0.300	0	-6	-12	-18	-24
DTT ε_f ≥ 1.00%	0	-6	-12	-18	-24

Max. Design Temp.	PG 82				
Min. Design Temp.	-10	-16	-22	-28	-34
Original DSR G*/sin δ ≥ 1.00 kPa	82				
RTFO DSR G*/sin δ ≥ 2.20 kPa	82				
PAV 20 hours, 2.10 MPa	100(110)				
PAV DSR G*sin δ ≤ 5000 kPa	40	37	34	31	28
BBR S ≤ 300 MPa, m ≥ 0.300	0	-6	-12	-18	-24
DTT ε_f ≥ 1.00%	0	-6	-12	-18	-24

Three states of Binder Aging:

-ORIGINAL (NO AGING)

-RTFO Aging (to simulate plant production aging)

-PAV Aging (ultimate service life aging)

Current Binder Grading Systems

AASHTO M320

Current Binder Grading Systems

- AASHTO M332

Three states of Binder Aging:
-ORIGINAL (NO AGING)

-RTFO Aging (to simulate plant production aging)

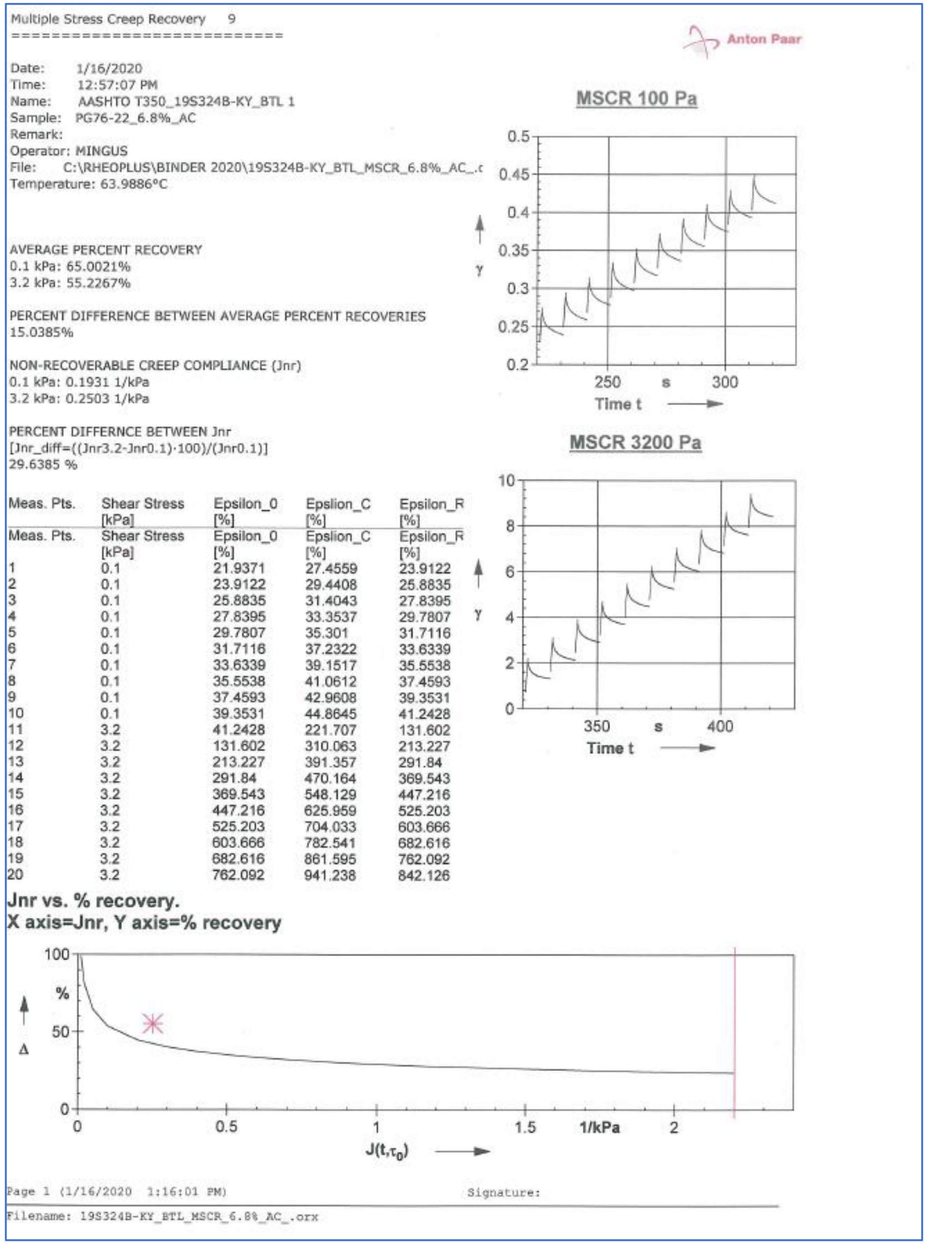
-PAV Aging (ultimate service life aging)

High PG	PG 52							PG 58					PG 64						
Low PG	-10	-16	-22	-28	-34	-40	-46	-16	-22	-28	-34	-40	-10	-16	-22	-28	-34	-40	-10
Original																			
≥230 °C	**Flash Point,** AASHTO T 48																		
≤ 3 Pa-s	**Rotational Viscosity** @ 135° C, AASHTO T 316																		
≥ 1.00 kPa (S H V E)	**DSR G*/sin** δ (Dynamic Shear Rheometer), AASHTO T 315																		
	52							58					64						
RTFO (Rolling Thin Film Oven), AASHTO T 240																			
≤ 1.00%	**Mass Change**																		
S ≤ 4.5 kPa⁻¹ / H ≤ 2.0 kPa⁻¹ / V ≤ 1.0 kPa⁻¹ / E ≤ 0.5 kPa⁻¹	**MSCR $J_{nr, 3.2}$** (Multiple Stress Creep-Recovery), AASHTO T 3																		
	52							58					64						
≤ 75% (S H V E)	**MSCR $J_{nr, Diff}$** (Multiple Stress Creep-Recovery), AASHTO T 3																		
	52							58					64						
PAV (Pressure Aging Vessel), AASHTO R28																			
	90							100					100						
S ≤ 5000 kPa / H ≤ 6000 kPa / V ≤ 6000 kPa / E ≤ 6000 kPa	**DSR G*sin** δ (Dynamic Shear Rheometer), AASHTO T 315																		
	25	22	19	16	13	10	7	25	22	19	16	13	31	28	25	22	19	16	34
S ≤ 300 MPa, m ≥ 0.300	**BBR S (creep stiffness) & m-value** (Bending Beam R																		
	0	-6	-12	-18	-24	-30	-36	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	-30	0

• If BBR m-value ≥ 0.300 and creep stiffness is between 300 and 600, the Direct Tension failure strain requirement of ≥ 1.00% can be used in lie
• Binder shall be homogeneous, free from water, contain no deleterious materials, be at least 99.0% soluble and contain no particles larger than

Binder Recovery & Extraction

Multiple Stress Creep Recovery (MSCR) DSR Data File for an extracted, recovered PG 76-22 mix with 30 % RAP



Multiple Stress Creep Recovery 9
===========================

Date: 1/16/2020
Time: 12:57:07 PM
Name: AASHTO T350_19S324B-KY_BTL 1
Sample: PG76-22_6.8%_AC
Remark:
Operator: MINGUS
File: C:\RHEOPLUS\BINDER 2020\19S324B-KY_BTL_MSCR_6.8%_AC_.c
Temperature: 63.9886°C

AVERAGE PERCENT RECOVERY
0.1 kPa: 65.0021%
3.2 kPa: 55.2267%

PERCENT DIFFERENCE BETWEEN AVERAGE PERCENT RECOVERIES
15.0385%

NON-RECOVERABLE CREEP COMPLIANCE (Jnr)
0.1 kPa: 0.1931 1/kPa
3.2 kPa: 0.2503 1/kPa

PERCENT DIFFERNCE BETWEEN Jnr
[Jnr_diff=((Jnr3.2-Jnr0.1)·100)/(Jnr0.1)]
29.6385 %

Meas. Pts.	Shear Stress [kPa]	Epsilon_0 [%]	Epslion_C [%]	Epsilon_R [%]
Meas. Pts.	Shear Stress [kPa]	Epsilon_0 [%]	Epslion_C [%]	Epsilon_R [%]
1	0.1	21.9371	27.4559	23.9122
2	0.1	23.9122	29.4408	25.8835
3	0.1	25.8835	31.4043	27.8395
4	0.1	27.8395	33.3537	29.7807
5	0.1	29.7807	35.301	31.7116
6	0.1	31.7116	37.2322	33.6339
7	0.1	33.6339	39.1517	35.5538
8	0.1	35.5538	41.0612	37.4593
9	0.1	37.4593	42.9608	39.3531
10	0.1	39.3531	44.8645	41.2428
11	3.2	41.2428	221.707	131.602
12	3.2	131.602	310.063	213.227
13	3.2	213.227	391.357	291.84
14	3.2	291.84	470.164	369.543
15	3.2	369.543	548.129	447.216
16	3.2	447.216	625.959	525.203
17	3.2	525.203	704.033	603.666
18	3.2	603.666	782.541	682.616
19	3.2	682.616	861.595	762.092
20	3.2	762.092	941.238	842.126

Jnr vs. % recovery.
X axis=Jnr, Y axis=% recovery

Page 1 (1/16/2020 1:16:01 PM) Signature:
Filename: 19S324B-KY_BTL_MSCR_6.8%_AC_.orx

Asphalt Binder Terminology

BINDER GRADE VERIFICATION (M320) [Run on binder of reported grade]

- COC, Brookfield, Original DSR, %Mass Loss, RTFO DSR,PAV DSR, BBR

BINDER GRADE CLASSIFICATION [Run on binder of reported grade but to determine continuous grading]

- COC, Brookfield, Original DSR @ 2 temps., %Mass Loss, RTFO DSR @ 2 temps., PAV DSR @ 2 temps., BBR @ 2 temps.

BINDER GRADE CLASSIFICATION [Run on binder of unknown grading]

- COC, Brookfield, Original DSR @ multiple temps, % Mass Loss, RTFO DSR @ multiple temps, PAV DSR @ multiple temps, BBR @ 2 temps(minimum)
- Extracted/Recovered Binder from Mix containing RAP run at multiple high temps and BBR @ 2 temps.
- Extracted/Recovered Binder from Mix containing RAS run at multiple high temps and BBR @ 2 temps.
- Extracted/Recovered Binder from RAP/RAS run at multiple high temps and BBR @ 2 temps.

Continuous Grading Temperatures and Continuous Grades for PG Binders

(8/11/15)

(ASTM D7643)

DATE:

PROJECT: PG 76-22 w/FRAP, @ 5.9 %ac

TECH: SQ

CONTINUOUS GRADE:
PG 86.7-23.5

PG GRADE:
PG 82-22

BINDER PROPERTY TO Determine	SPECIFICATION REQUIREMENT (PS)	LOWER TEST TEMPERATURE (T1) (°C)	UPPER TEST TEMPERATURE (T2) (°C)	LOWER TEST TEMPERATURE PROPERTY (P1)	UPPER TEST TEMPERATURE PROPERTY (P2)	CALCULATED CONTinuous GRADING TEMPERATURE (TC)	SCALE USED FOR INTERPOLATION
ORIGINAL DSR	**1.00**	**88**	**94**	**1.18**	**0.69**	**89.85**	**log (10) scale**
RTFO DSR	**2.20**	**82**	**88**	**3.4**	**1.94**	**86.66**	
PAV DSR	**5000**	**22**	**25**	**6140**	**4470**	**23.94**	
m-value	**0.300**	**-18**	**-12**	**0.267**	**0.311**	**-23.50**	**arithmetic scale**
Creep Stiffness	**300**	**-18**	**-12**	**321**	**157**	**-27.43**	**log (10) scale-10 C**

LOG10 Formula= T1+((LOG10(PS)-LOG10(P1))/(LOG10(P2)-LOG10(P1))*(T2-T1 (for Upper & Intermediate Temps)

ARITHMETIC SCALE=T1+((PS-P1)/(P2-P1))*(T2-T1)-10 C (for m-value)

LOG10 Formula= T1+((LOG10(PS)-LOG10(P1))/(LOG10(P2)-LOG10(P1))*(T2-T1)-10 (For Creep Stiffness)

Delta Tc=(Tc[Creep Stiffness]-Tc[m-value])=-27.4-(-23.5)= -3.9

Use of Continuous Grading in BMD

- IF using high RECYCLE, good to know how continuous grading (especially low temp) compares back to performance test results
- NOTE OF CAUTION:
  - In extracting and recovering binder from mix [containing recycle] for binder grading, the solvent extraction process will get the majority of the virgin and recycle binder out of the mixture. There is much discussion that the RAP may only be contributing 80-85 % of its available binder and RAS maybe 50 % of its available binder in actual mix performance. The use of continuous binder grading against performance testing should be used cautiously. The resultant continuous binder grading may show higher HIGH temp values and lower LOW TEMP values than exist.

Balance Mix Design Case Study

NCAT TEST TRACK FINDINGS

Mix Design

Fine-Graded vs. Coarse-Graded Mixtures. In the early years of Superpave implementation, coarse-graded mixtures were promoted to improve rutting resistance. However, that notion was called into question when the results of Westrack showed that a coarse-graded gravel mix was less resistant to rutting and fatigue cracking than a fine-graded mix with the same aggregate. In the first cycle of the NCAT Test Track, the issue was examined more completely. Twenty-seven sections were built with a wide range of aggregate types to compare coarse-, intermediate-, and fine-graded mixtures. Results demonstrated that fine-graded Superpave mixes perform as well as coarse-graded and intermediate-graded mixes under heavy traffic and tend to be easier to compact, less prone to segregation, less permeable, and quieter (*1*). Based on these findings, many state highway agencies revised their specifications to encourage or require more fine-graded mix designs.

Fine graded mixtures work well.

NCAT TEST TRACK FINDINGS

Design Gyrations. Another mix design issue dealt with the number of gyrations (N_{design}) used to compact specimens for mix design and quality assurance testing. The performance of mixes on the Test Track, along with data from field projects across the U.S. collected as part of NCHRP project 9-29 (*2*), demonstrated the Superpave N_{design} levels specified in AASHTO R 35 are too high. High N_{design} numbers tend to grind aggregate particles and break them down much more than what occurs during construction or under traffic, so high N_{design} levels do not represent what actually occurs in pavements. Some mix designers use coarse gradations to meet the volumetric mix design criteria, but those mixes are more challenging to compact in the field and tend to be more permeable, making the pavements less durable (*3*). Numerous Superpave and SMA mixes on the Test Track designed with 50 to 70 gyrations in the Superpave gyratory compactor (SGC) have held up to the heavy loading with great performance (*1*). Many states significantly reduced their N_{design} levels as a result of these findings on the Test Track.

Many states significantly reduced their Ndesign levels as a result of findings at the Test Track

NCAT TEST TRACK FINDINGS

Binder Characteristics

Effect of Binder Grade on Rutting. Superpave guidelines recommend using a higher PG grade for high-traffic volume roadways to minimize rutting. Results from the first cycle of testing showed that permanent deformation was reduced by an average of 50% when the high temperature grade was increased from PG 64 to PG 76 (*8*). This two-grade bump is typical for heavy traffic projects. These results validated one of the key benefits of modified asphalt binders. Also, Alabama DOT sponsored test sections in the first cycle to evaluate surface mixes designed with 0.5 percent more asphalt binder. Results of those sections showed that increasing the asphalt content of mixes containing modified binders did not adversely affect rutting resistance; however, mixes produced with neat binders were more susceptible to rutting in very high traffic conditions such as on the Test Track (*8*). Further analysis of rutting data in the second cycle considered many other mix design factors such as volumetric properties, aggregate gradation parameters, and SGC compaction indices. This analysis showed that the most influential factor on rutting was the binder high temperature performance grade (*1*).

..the most influential factor on rutting was the binder high temperature performance grade


NCAT TEST TRACK FINDINGS

Relationships between Laboratory Results and Field Performance

Air Voids. Air voids in laboratory-compacted specimens is one of the most common pay factors for asphalt pavements. The Indiana DOT sponsored research in the third cycle to identify an appropriate lower limit for this acceptance parameter. Surface mixes were intentionally produced with air voids between 1.0 and 3.5% by adjusting the aggregate gradation and increasing the asphalt content. Results showed that rutting increased significantly when the air voids were less than 2.75% (*12*). When test results are below that value and the roadway is to be subjected to heavy traffic, removal and replacement of the surface layer is appropriate. It is important to note that the experiment used only virgin mixes with neat (unmodified) asphalt binder. Other surface mixes containing modified binders or high recycled asphalt binder ratios that were produced with air voids below 2.5% have held up very well under the extreme traffic on the track.

Balance Mix Design Case Study

- KYTC CL 3 ASPH SURF 0.38D
- AGGREGATE:
  - Limestone #8’s @ 34.0 %
  - Natural Sand @ 5.0 %
  - Washed Limestone Sand @ 30.0 %
  - Baghouse Fines @ 1.0 %
  - Fine RAP @ 30.0 % (RAP %ac=5.0 %)
- BINDERS USED:
  - PG 58-28 (unmodified)
    - Continuous Grade=PG 60.5-29.5
  - PG 76-22 (SBS Modified)
    - Continuous Grade=PG 78.4-25.0

Mix Design Conditions

- All specimens (for both PG 58-28 and PG 76-22) used the same cold feed %'s and the same weighup for all volumetric and performance test specimens
- All volumetric specimens short term aged at compaction temperature for 2 hours(per AASHTO R30)
- All performance test specimens short term aged for mechanical property testing at 4 hours at 135°C
- All volumetric specimens compacted using 65 gyrations
- Bulk specific gravity of compacted specimens by AASHTO T166 (Gmb)
- Theoretical maximum specific gravity of the mix by AASHTO T209.

PG 58-28 Volumetric and Performance Data

% AC	SPECIMEN #	% AIR VOIDS	%VMA	%VFA	%Gmm @ Ninitial	IDEAL CT-INDEX (---)	I-FIT (---)	HAMBURG RUT DEPTH (mm)	APA RUT DEPTH (mm)	CANTABRO LOSS (%)	HTIDT (psi)	PG Continuous Grade
5.3	1				86.2							
	2				86.2							
AVERAGE		5.1	16.2	68.7	86.2	83.6	5.6	5.48	5.12	4.9	29.5	**PG 67.9-26.0**
5.8	1				86.7							
	2				86.6							
AVERAGE		4.2	16.5	74.6	86.7	216.1	8.7	11.01	6.04	4.2	22.8	**PG 67.6-26.8**
6.3	1				87.4							
	2				87.4							
AVERAGE		3.5	17.0	79.3	87.4	223.1	20.6	fail	7.73	3.8	18.9	**PG 67.1-28.9**
0.0	1				#DIV/0!							
	2				#DIV/0!							
AVERAGE		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.0	0.0	0.00	11.65	0.0		

PAIKY

Bluegrass Testing

PG 76-22 Volumetric and Performance Data

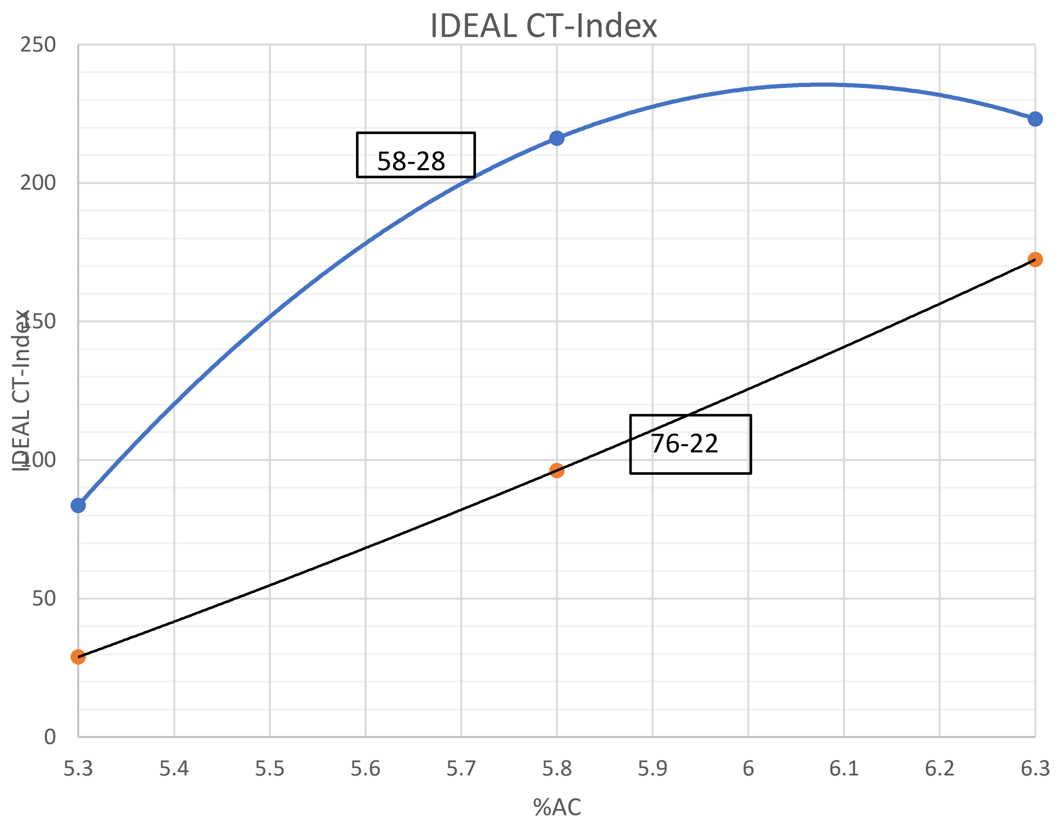
% AC	SPECIMEN #	% AIR VOIDS	%VMA	%VFA	%Gmm @ Ninitial	IDEAL CT-INDEX (---)	I-FIT (---)	HAMBURG RUT DEPTH (mm)	APA RUT DEPTH (mm)	CANTABRO LOSS (%)	HTIDT (psi)	PG Continuous Grade
5.3	1				86.0							
	2				86.1							
AVERAGE		5.0	16.2	69.2	86.1	28.9	1.6	1.34	2.00	5.9	70.7	PG 87.3-19.8
5.8	1				87.2							
	2				86.7							
AVERAGE		3.7	16.1	77.0	87.0	96.2	3.0	3.40	3.14	5.1	55.5	PG 85-4-21.0
6.3	1				88.5							
	2				88.5							
AVERAGE		2.1	15.8	86.8	88.5	172.3	8.9	5.63	3.34	4.7	50.9	PG 86.7-23.5
6.8	1				88.9							
	2				89.0							
AVERAGE		1.4	16.3	91.5	88.9	162.0	11.9	8.97	2.84	0.0	44.4	PG 80.0-23.5

Comparison of PG 58-28 and PG 76-22 IDEAL CT-Index Data

IDEAL CT-Index:	PG 58-28	PG 76-22
5.3 %ac	83.6	28.9
5.8 %ac	216.1	96.2
6.3 %ac	223.1	172.3
6.8 %ac	-----------	162.0

- Observations:

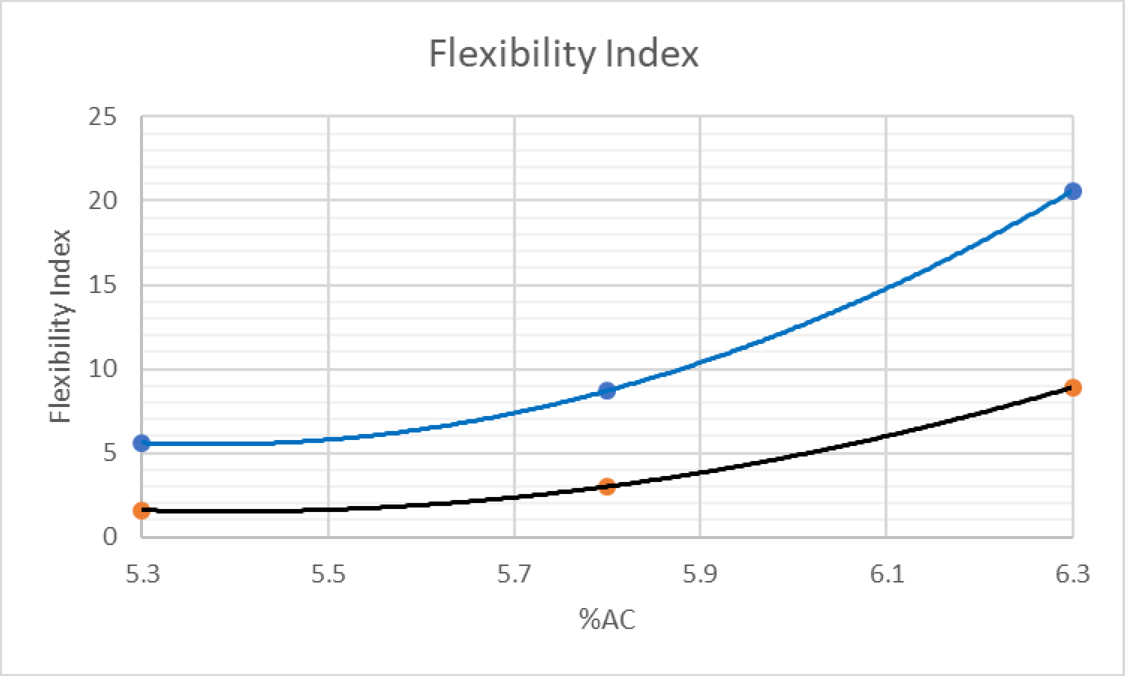
1. PG 76-22 at 5.3 % ac has extremely low value.
2. If CT minimum was 100, PG 58-28 would satisfy at 5.4%ac, PG 76-22 @ 5.9 %ac.



Comparison of PG 58-28 and PG 76-22 Performance Data

Flexibility Index:	PG 58-28	PG 76-22
5.3 %ac	5.6	1.6
5.8 %ac	8.7	3.0
6.3 %ac	20.6	8.9
6.8 %ac	-----------	11.9

- Observations:
- 1. If Flexibility Index of 8 was target, PG 58-28 would come in at 5.8 %ac, PG 76-22 would come in at 6.3 %ac.
- 2. PG 76-22 mix would show values indicating brittle nature @ 5.3 % and 5.8 %ac (up to 6.2 %ac).
- 3. To remember both mixes have 30 % RAP,and
- PG 58-28 mix would have ABR of 25.9 % and PG 76-22 mix would have ABR of 23.8 % at 6.3 %ac



Comparison of PG 58-28 and PG 76-22 Performance Data

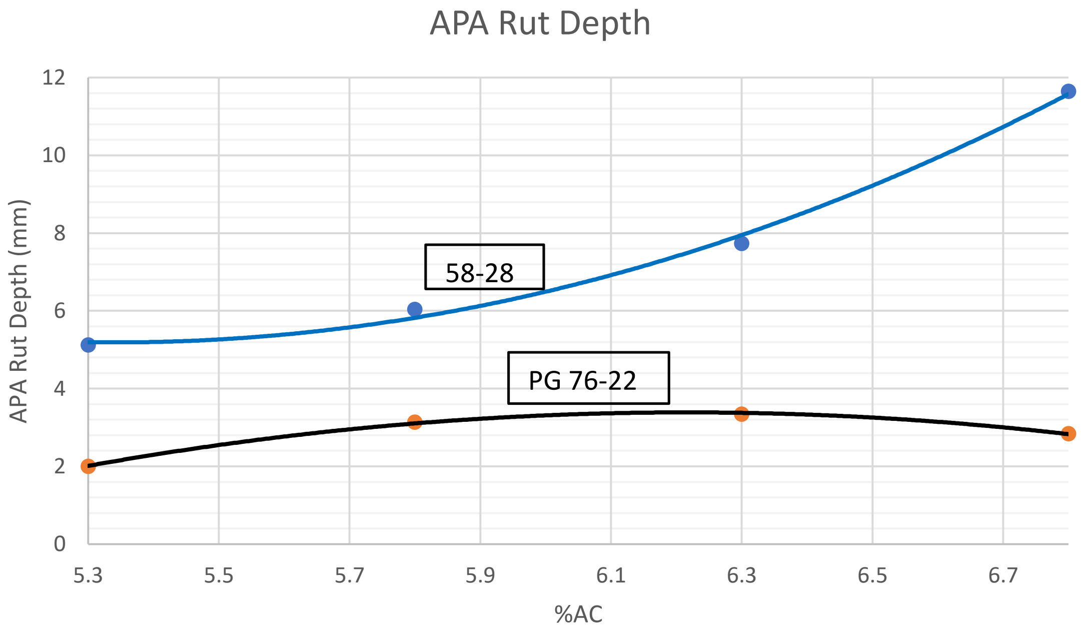
Hamburg Rut Depth:	PG 58-28	PG 76-22
5.3 %ac	5.48	1.34
5.8 %ac	11.01	3.40
6.3 %ac	---------	5.63
6.8 %ac	---------	8.97

- OBSERVATIONS:

1. The PG 58-28 mix had Hamburg values picked at 7500 passes.
2. The PG 76-22 mix had Hamburg values picked at 20,000 passes.
3. The PG 76-22 mix would pass on Hamburg Loaded Wheel specification limit of 12.5mm maximum rut depth beyond 6.8 %ac.
4. The PG 58-28 mix would pass on Hamburg Loaded Wheel specification limit of 12.5mm maximum rut depth at 5.8 %ac.

Comparison of PG 58-28 and PG 76-22 Asphalt Pavement Analyzer Data

APA Rut Depth:	PG 58-28	PG 76-22
5.3 %ac	5.12	2.00
5.8 %ac	6.04	3.14
6.3 %ac	7.73	3.34
6.8 %ac	11.65	2.84



OBSERVATIONS:

1. If using a specification limit of ≤8.0mm, the PG 58-28 mix would pass at 6.3 % ac, and the PG 76-22 mix would pass at an asphalt content greater than 6.8 %ac.

Comparison of PG 58-28 and 76-22 Performance Data

Continuous Grade:	PG 58-28	PG 76-22
5.3 %ac	PG 67.9-26.0	PG 87.3-19.8
5.8 %ac	PG 67.6-26.8	PG 85.4-21.0
6.3 %ac	PG 67.1-28.9	PG 86.7-23.5
6.8 %ac	----	PG 80.0-23.5

- OBSERVATIONS:
  - If using a PG 58-28 to offset the 30 % RAP in the mix and a PG 64-22 is the standard grade for the area, the PG 58-28 5.3% and 5.8% ac contents would maintain a low temperature grading ≥ -22 C and ≤ -28 C
  - The PG 76-22 gradings for the 5.3 and 5.8 %ac contents would indicate a low temperature grading less than the -22 C for the standard grading for the area.

Conclusions

PG 76-22 Mix:

- Volumetrically Optimized Design: % ac @ 5.8-5.9 %ac
- Performance Optimized Design:
  - IDEAL CT-Index versus Hamburg: minimum % ac 5.8%.
  - Flexibility Index versus Hamburg: minimum %ac 6.4 %

PG 58-28 Mix:

- Volumetrically optimized Design: %ac @ 6.3
- Performance Optimized Mix Design:
  - IDEAL CT-Index versus Hamburg: minimum % ac 5.8%.
  - Flexibility Index versus Hamburg: would look to redo design

PAIKY

Volumetrically Vs. Performance Optimized Designs

- Volumetrically Optimized Mix Design:
  - A mix design where design binder content is selected on the basis of satisfying target criteria for % air voids, % voids in the mineral aggregate(VMA), % voids filled with asphalt(VFA)
    - Moisture damage susceptibility testing @ design binder content
    - Some states use Marshall Mix Design, so Stability and Flow Analysis
- Performance Optimized Mix Design:
  - A mix design where design binder content is selected on the basis of satisfying criteria for performance tests for cracking and rutting
    - Moisture damage susceptibility testing @ design binder content
      - By Stripping Inflection Point (Hamburg Loaded Wheel)
      - By AASHTO T283, ASTM D4867
- <u>NOTE: Most present state specification limits for Crack Testing Limits are based on data derived from Present Volumetrically Optimized Mix Designs</u>
  - Will Performance Optimized Mix Design

Volumetrically Vs. Performance Optimized Designs

- CRACKING TEST:
  - Most present state specification limits for Crack Testing Limits are based on data derived from Present Volumetrically Optimized Mix Designs
- RUTTING TEST:
  - Most present state specification limits for Hamburg (Max. rut depth and test temperature) are based on recognized and accepted specification limits already being utilized
- QUESTION: Will Performance Optimized Mix Designs and the resulting test data have the potential to increase future specification limits?

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