Development of a Comprehensive Balanced Mix Design for MassDOT

2022 NEAUPG Annual Meeting

November 3rd, 2022 ● Albany, NY

Walaa S. Mogawer, P.E. (MA & RI), F.ASCE
Commonwealth Professor of Civil & Environmental Engineering
Director - Highway Sustainability Research Center
University of Massachusetts Dartmouth

UMass | Dartmouth

Research Team

Name	Affiliation
Walaa Mogawer, Ph.D., P.E.	HSRC/UMass Dartmouth
Alexander Austerman, P.E.	HSRC/UMass Dartmouth
Ahmed Soliman, Ph.D.	HSRC/UMass Dartmouth
Mr. Kevin Stuart	Consultant
Fujie Zhou, Ph.D., P.E.	Texas Transportation Institute - Texas A&M
Thomas Bennert, Ph.D.	Rutgers University
Michael Elwardany, Ph.D., P.E.	Florida State University

Acknowledgement

❑ Edmund Naras	MassDOT
❑ Mark Brum	MassDOT
❑ Mike Nichols	Aggregate Industries US
❑ Jeff Lewis	Brox Industries
❑ Mike Barry	Peckham

Balanced Mix Design (BMD)

Definition (AASHTO PP 105-20)

"Balanced Mix Design: is an asphalt mix design using performance test on appropriately conditioned specimens that address multiple modes of distress taking into consideration mix aging, traffic, climate, and location within the pavement structure."

UMass | Dartmouth

Balanced Mix Design (BMD)

- Four Approaches (AASHTO PP 105-20)
  - Volumetric Design with Performance Verification
  - Volumetric Design with Performance Optimization
  - Performance-Modified Volumetric Design
  - Performance Design

Questions to be Addressed in a Comprehensive BMD Procedure

- ❑ Which approach to use and why?
- ❑ Which distresses to include?
- ❑ Which performance test(s) to use?
- ❑ How to determine the pass/fail criteria?
- ❑ What aging protocol to use for the performance testing during mix design?
- ❑ What aging protocol to use for the performance testing during QC/QA?
- ❑ What aging protocol to use for distresses that occurs at a later stage of pavement life?
- ❑ What impact does production tolerances have on a BMD during production?

Study Objective

- To develop a Comprehensive Balanced Mixture Design (BMD) Procedure for Massachusetts that addresses these questions:
  - Which approach to use and why?
  - Which distresses to include?
  - Which performance test(s) to use?
  - How to determine the pass/fail criteria?
  - What aging protocol to use for the performance testing during mix design?
  - What aging protocol to use for the performance testing during QC/QA?
  - What aging protocol to use for distresses that occurs at a later stage of pavement life?
  - What impact does production tolerances have on a BMD during production?

Which Approach to Use and Why?

- Which Approach?
  - Volumetric Design with Performance Verification
- Why?
  - Simplicity and Familiarity
  - Not enough data to verify reliability of performance tests

Which Distresses to include?

- An internet survey was administered to all New England SHA's in 2019 to determine the predominate distresses experienced.

- In the survey, MassDOT identified fatigue cracking as the predominate distress.

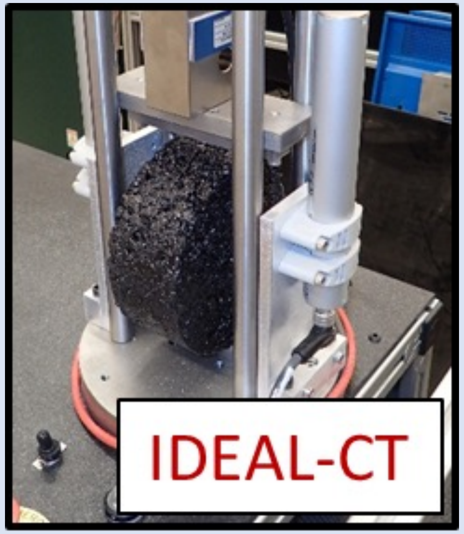
Which Performance Tests to Use?

- Test Selection Considerations
  - Easy to conduct
  - Do not require expensive equipment
  - Utilize samples that can be easily fabricated using the Superpave Gyratory Compactor
  - Test method AASHTO or ASTM standardized
  - Do not require any extensive preparation (gluing to plates, etc.) if possible

Performance Tests: Fatigue Cracking

Semi-Circular Bend AASHTO T393
(Flexibility Index Test or FIT)

IDEAL-CT Test ASTM D8225



UMass | Dartmouth

Performance Tests: Rutting

- MassDOT already requires testing of all mixtures using the HWTT (AASHTO T324) for **rutting**. This test and associated established criteria will be utilized in the development of the BMD procedure.

UMass | Dartmouth

Mixture Performance Testing

Rutting

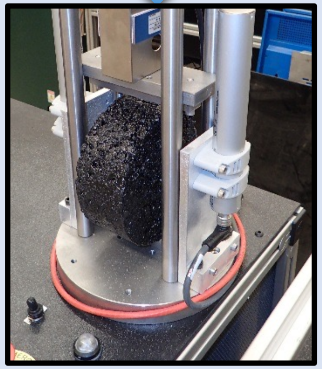
High Temperature

Hamburg Wheel Tracking Device (HWTD) Test

Cracking

Intermediate Temperature

IFIT



IDEAL-CT

1. Illinois Flexibility Index Test (IFIT)
2. Indirect Tensile Asphalt Cracking Test (IDEAL-CT)

How to Determine Pass/Fail Criteria?

Three Approaches can be used:

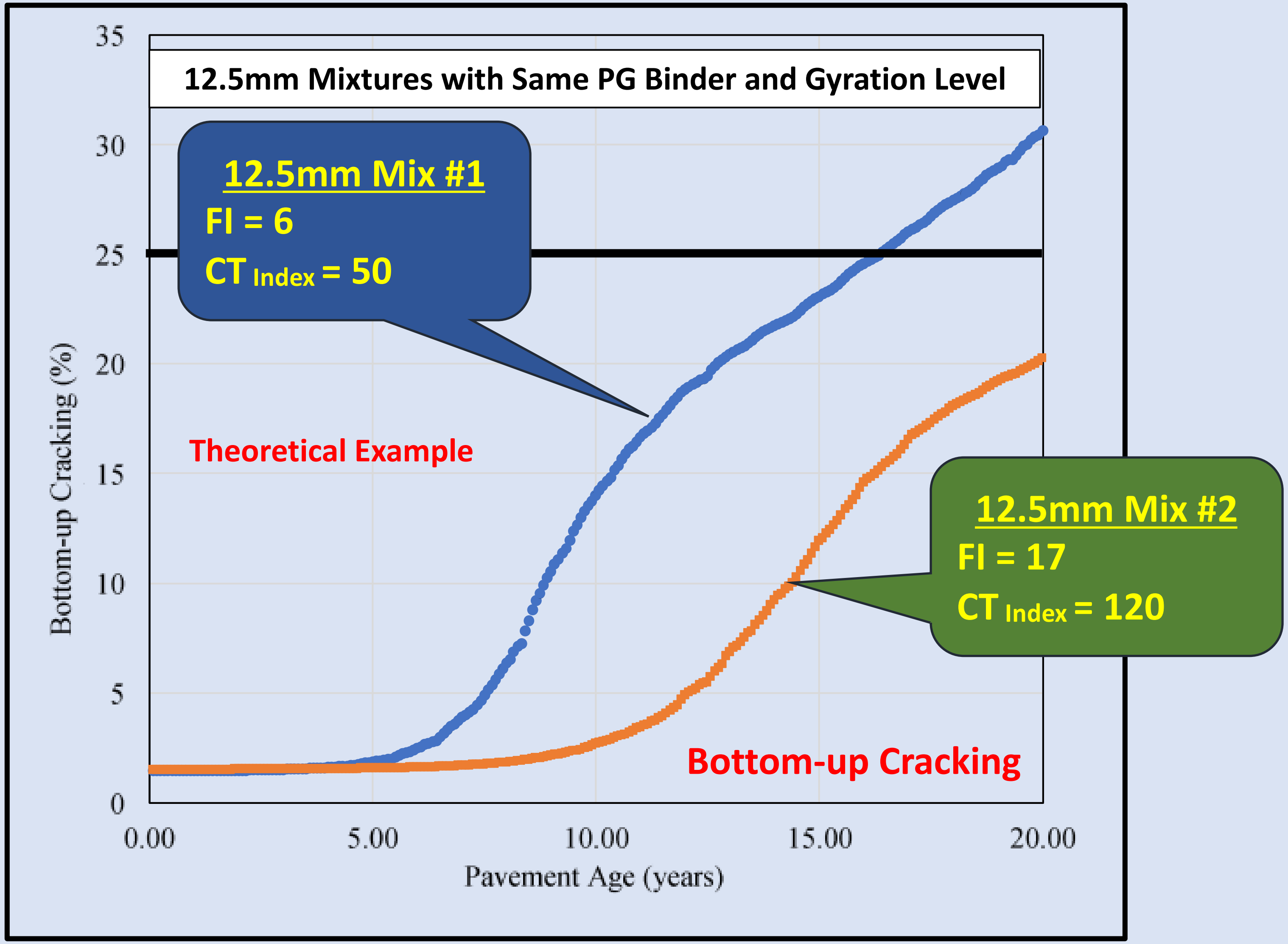
1. Statistics using lab data

2. Predictive models + Lab Data
Predict distress using AASHTOWare® Pavement ME and combine with FI and CT_{Index} lab data already measured.

3. Field core testing of pavements of known age that exhibit excellent performance.

UMass | Dartmouth

Approach 2: Predictive Models + Lab Data

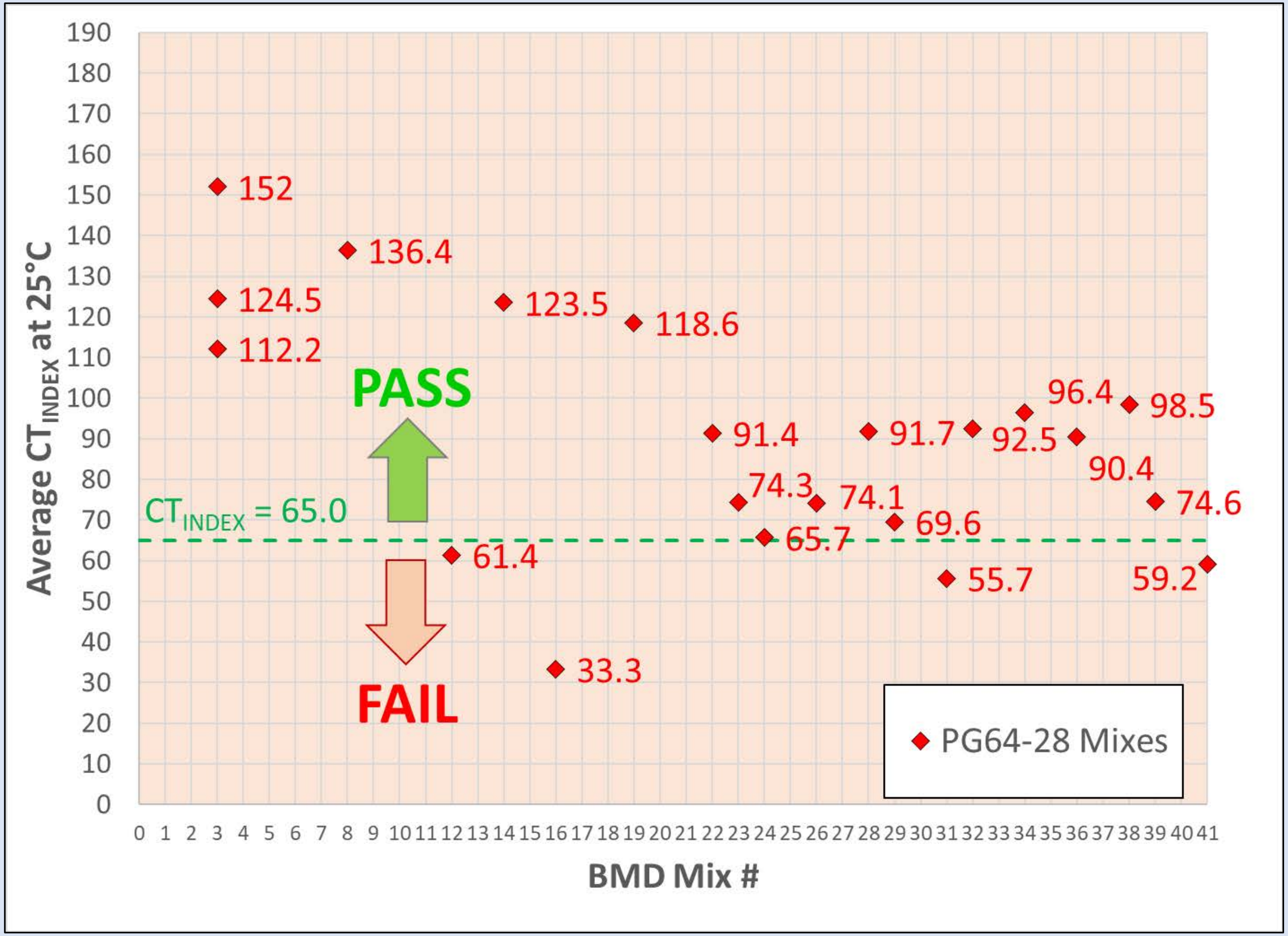


Approach 2: Predictive Models + Lab Data

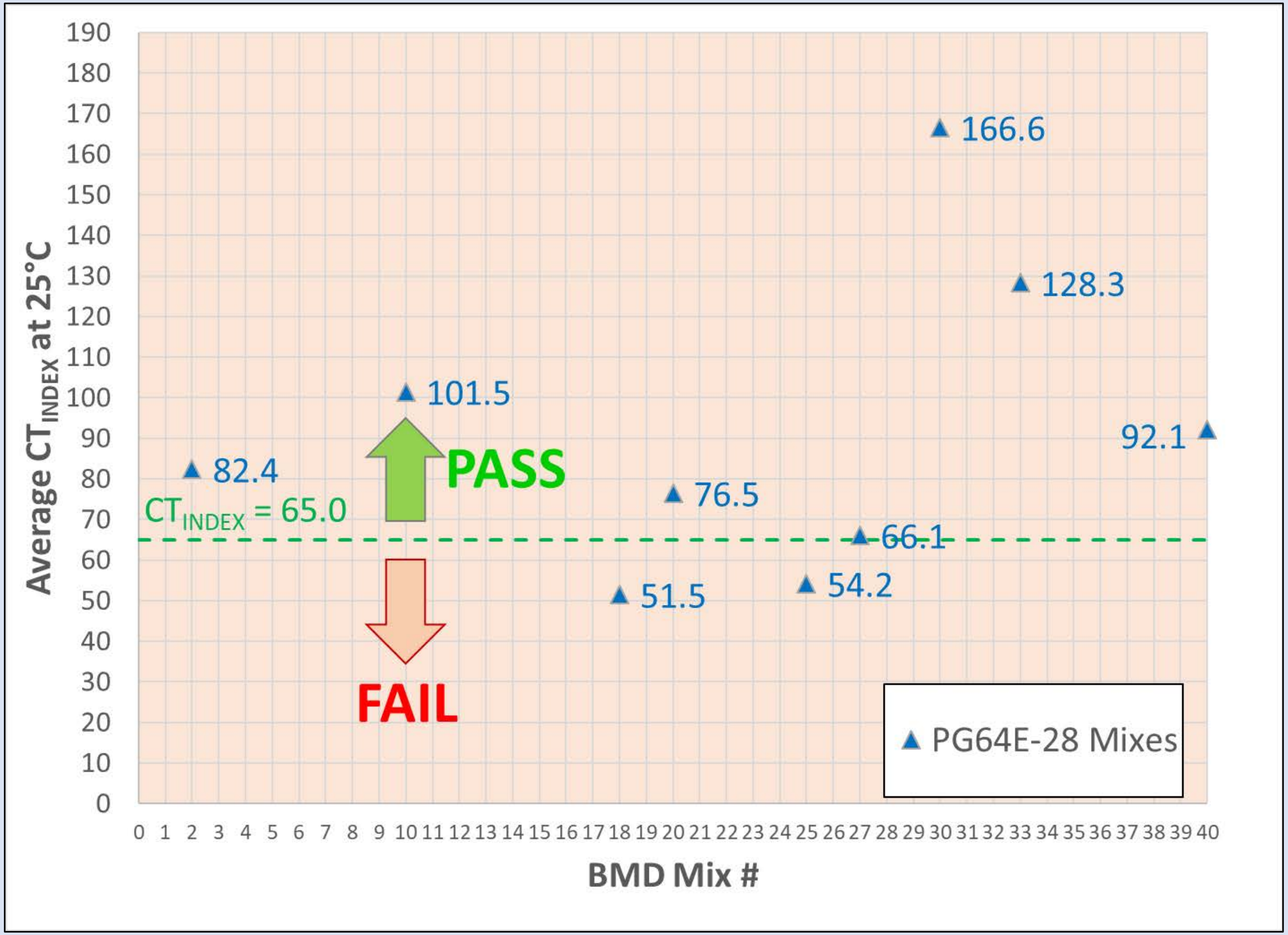
- Distress curves should help identify the mixtures that perform well and poor. The corresponding values of FI and CT_{Index} can be used to identify the appropriate test thresholds corresponding to good predicted performance.

- Done for STOA and LTOA.

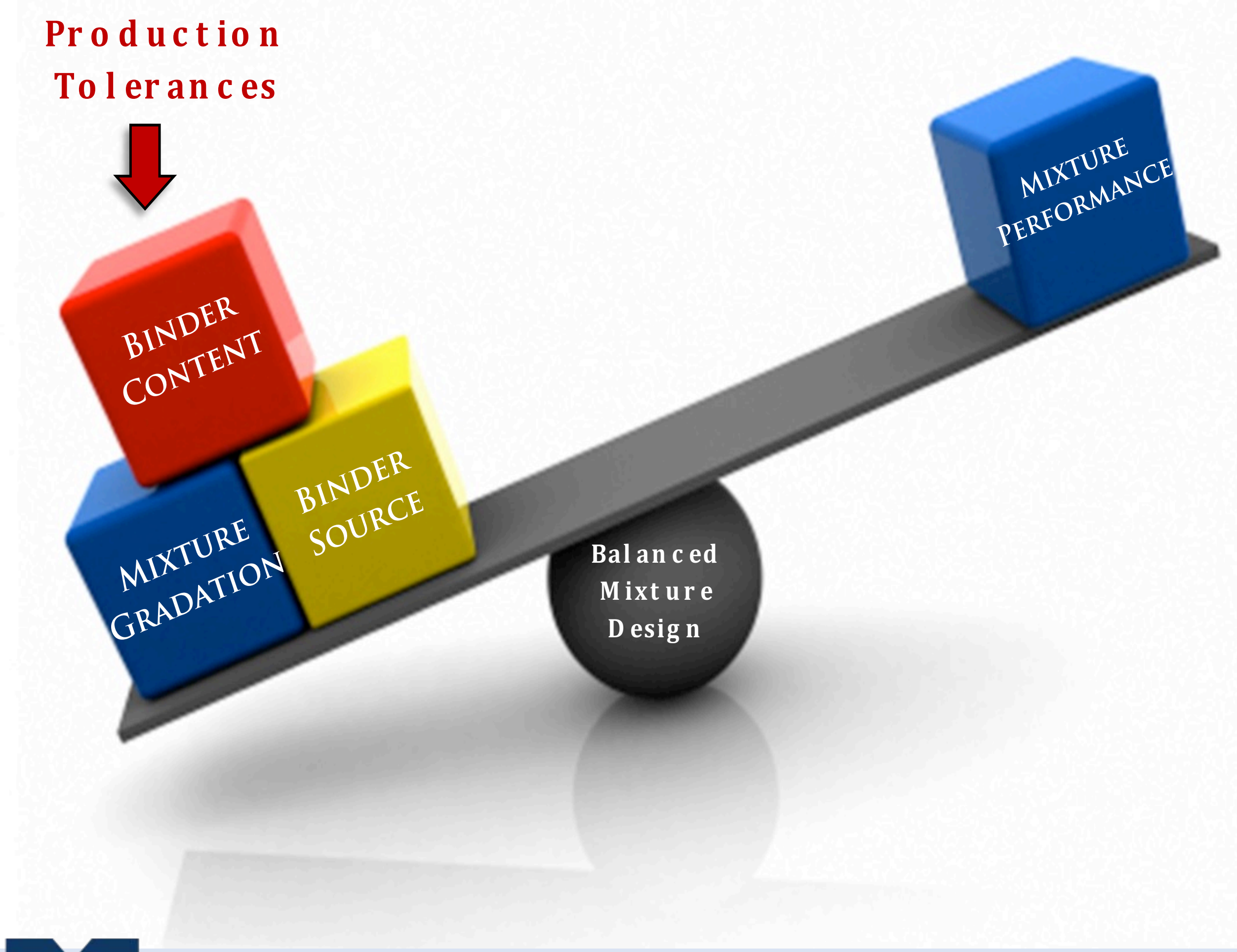
Ideal-CT Results: PG64S-28 Mixtures



Ideal-CT Results: PG64E-28 Mixtures



What impact does production tolerances have on a BMD during production?



- Binder content, mixture gradations, source of the asphalt binder, etc. are all dynamic during production.
- Binder content and gradations are governed by the production tolerances in a specification.
- Binder source is not governed and may vary during production or season-to-season.

Production Tolerances

MassDOT Quality Assurance Specification for Hot Mix Asphalts Section 450 was utilized to determine the acceptable tolerances:

1. Asphalt Binder Content

   ±0.3% of the design optimum

2. Aggregate Gradation

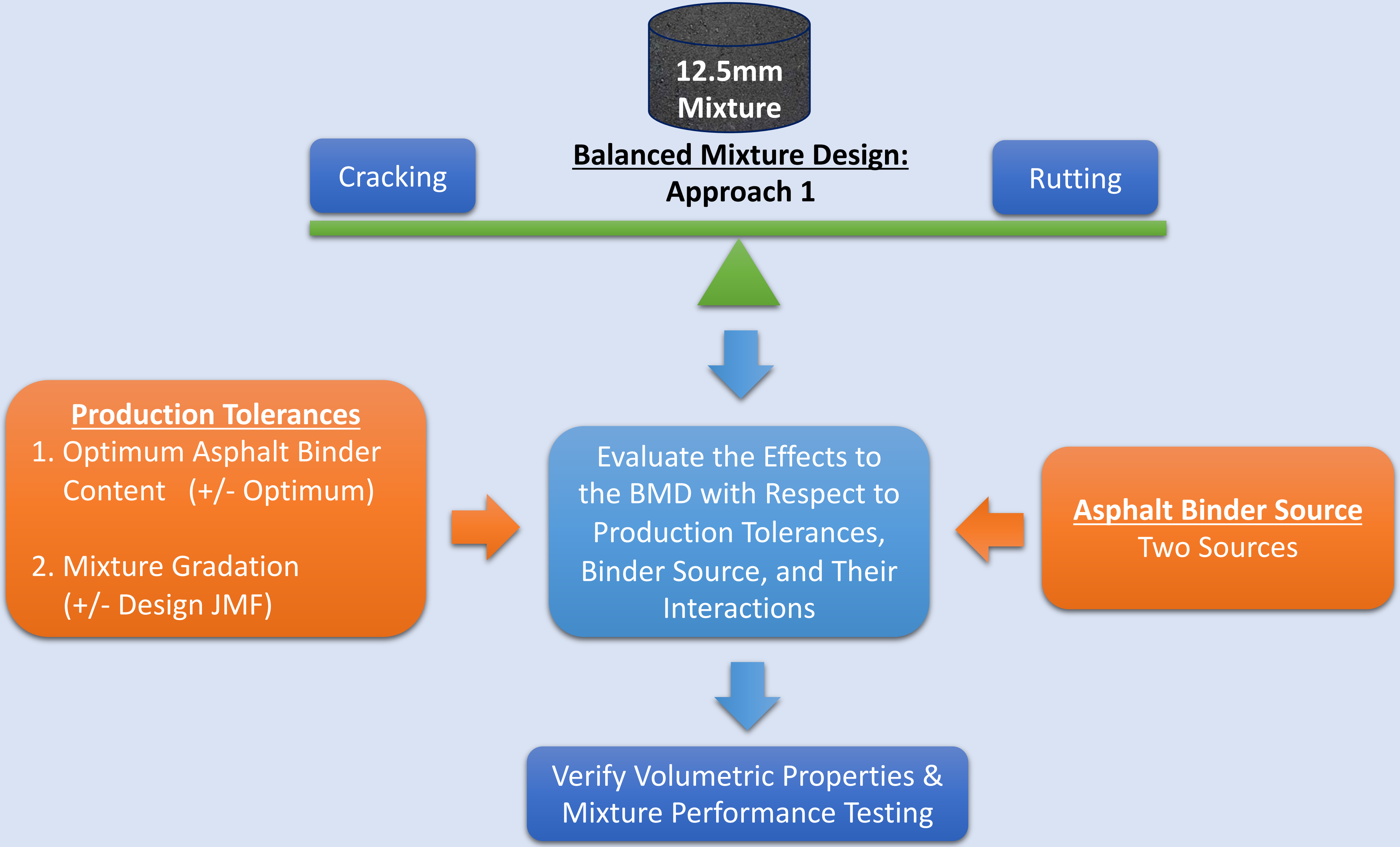
   Allowable deviation from Job Mix Formula varies by individual sieve size.

3. Asphalt Binder Source (*not part of MassDOT QA Specifications)*

   Two different PG64-28 asphalt binders from different sources were utilized, designated as A and B.

UMass | Dartmouth

Experimental Plan



Production Tolerances – Aggregate Gradation

Sieve Size (mm)	Design Gradation	Production Tolerance	Coarse Gradation	Fine Gradation
19.0	100	-	100	100
12.5	94.0	±6	88	100
9.5	86.0	±6	80	92
4.75 (No. 4)	61.0	±6	55	67
2.36 (No. 8)	42.0	±5	37	47
1.18 (No. 16)	29.0	±3	26	32
0.60 (No. 30)	19.0	±3	16	22
0.30 (No. 50)	13.0	±3	10	16
0.15 (No. 100)	7.0	±2	5	9
0.075 (No. 200)	4.0	±1	3	5

Production Tolerances – Asphalt Binder Source

- PG64-28 was obtained from two different sources.

- The two binder sources had the same PG, equivalent continuous PGs, but different relaxation properties.

Binder Source	Continuous Grade	PG Grade
A	66.2-28.4	PG64-28
B	65.6-27.7	PG64-28 (Borderline)

Production Tolerances and Asphalt Binder Source: Effects on Volumetric Properties

Binder Source	Mixture Gradation	Asphalt Binder Content	Average Air Voids
A	Coarse	Lower Limit (-0.3%)	6.3 **F**
		Optimum	5.0
		Upper Limit (+0.3%)	4.3
	Design	Lower Limit (-0.3%)	5.0
		Optimum	4.1
		Upper Limit (+0.3%)	2.9
	Fine	Lower Limit (-0.3%)	4.7
		Optimum	3.7
		Upper Limit (+0.3%)	2.6 **F**

Binder Source	Mixture Gradation	Asphalt Binder Content	Average Air Voids
B	Coarse	Lower Limit (-0.3%)	5.9 **F**
		Optimum	4.7
		Upper Limit (+0.3%)	4.0
	Design	Lower Limit (-0.3%)	4.0
		Optimum	3.2
		Upper Limit (+0.3%)	2.4 **F**
	Fine	Lower Limit (-0.3%)	4.6
		Optimum	3.5
		Upper Limit (+0.3%)	2.5 **F**

F = Failed the 4 ±1.3% production tolerance.

Intermediate Temperature Cracking Results – IDEAL- CT

Binder Source	Mixture Gradation	Asphalt Binder Content	Average CT_{Index}
A	Coarse	Lower Limit (-0.3%)	79.9
		Optimum	94.8
		Upper Limit (+0.3%)	114.2
	Design	Lower Limit (-0.3%)	61.8 F
		Optimum	105.4
		Upper Limit (+0.3%)	120.9
	Fine	Lower Limit (-0.3%)	70.8
		Optimum	99.6
		Upper Limit (+0.3%)	122.9
B	Coarse	Lower Limit (-0.3%)	71.3
		Optimum	71.7
		Upper Limit (+0.3%)	116.4
	Design	Lower Limit (-0.3%)	60.6 F
		Optimum	87.4
		Upper Limit (+0.3%)	100.9
	Fine	Lower Limit (-0.3%)	49.9 F
		Optimum	87.3
		Upper Limit (+0.3%)	139.3

F = Failed the proposed minimum CT_{Index} criteria of 65.

What impact does production tolerances have on a BMD during production?

- A balanced mixture design can become unbalanced when produced because of normal production variabilities.

What Aging Protocol to Use for the Performance Testing During Mix Design?

- Short Term Aging (STOA)
  - Loose mix
  - Loose mix thickness: 1.5 – 2.0 inches (AASHTO R 30)
  - Duration: 4 hrs
  - Temperature: compaction temperature

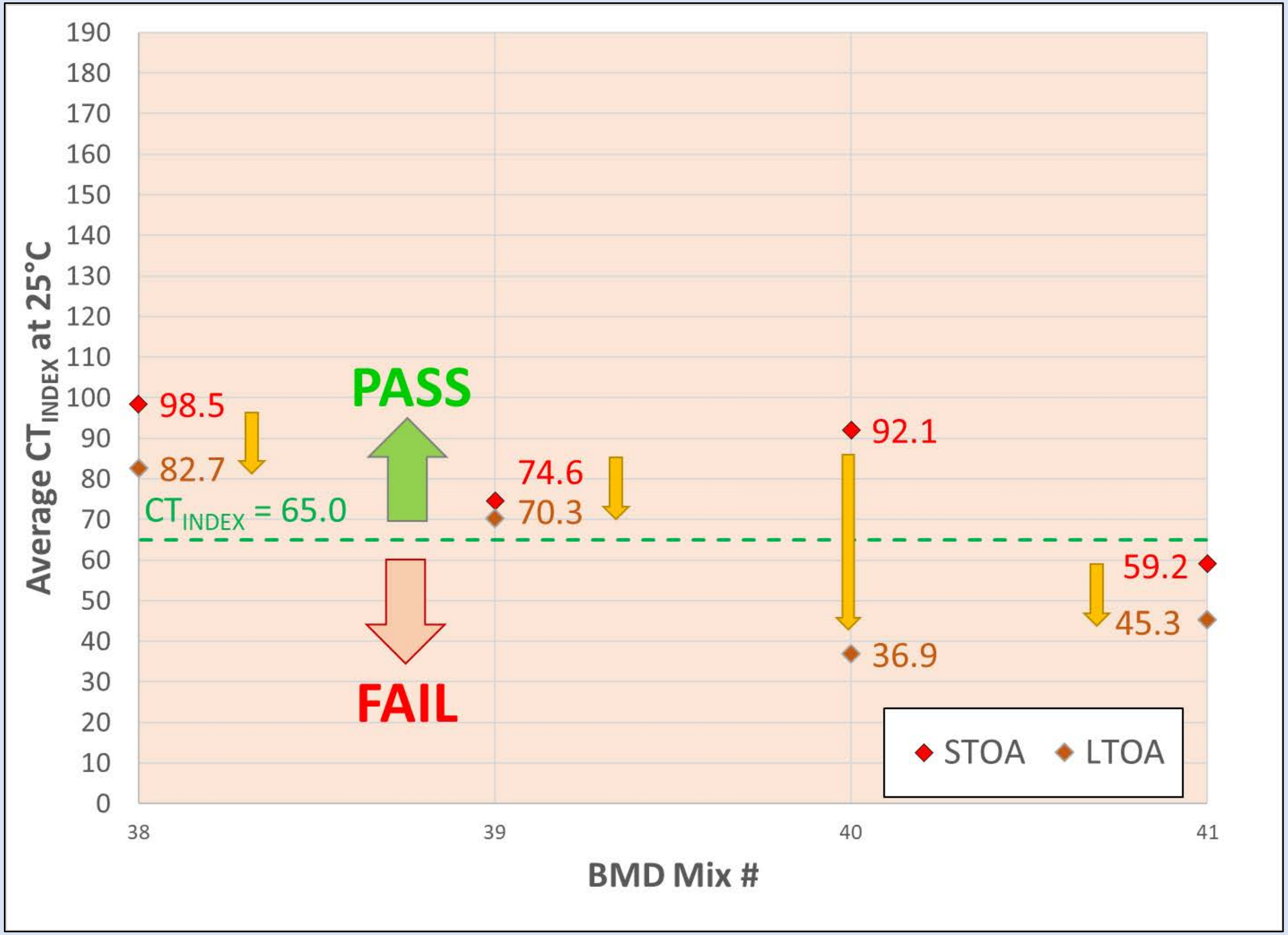
What Aging Protocol to Use for the Performance Testing During QC/QA?

- Short Term Oven Aging (STOA)
    - Loose mix
    - Loose mix thickness: 1.5 – 2.0 inches (AASHTO R 30)
    - Duration: 4 hrs
    - Temperature: compaction temperature

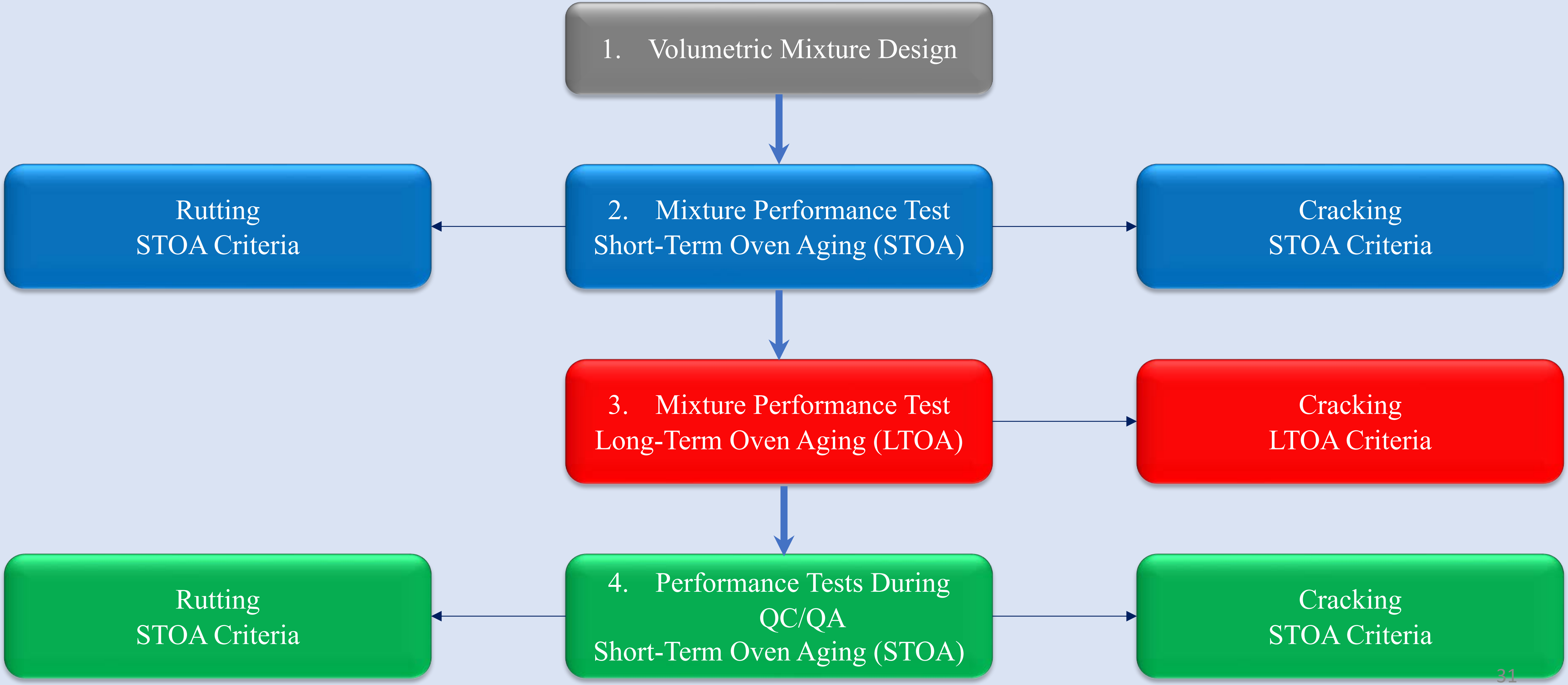
What aging protocol to use for distresses that occurs at a later stage of pavement life?

- Long-Term Oven Aging (LTOA)
  - ❑Loose mix
  - ❑Loose mix thickness: 1.5 – 2.0 inches (AASHTO R 30)
  - ❑Duration: STA followed by 20 hours
  - ❑Temperature: STA at compaction temperature followed by 20 hours at 100°C

Ideal-CT Results: STOA vs. LTOA Aging



Outcome of the Study: Comprehensive BMD



Questions/Comments

Thank you