Balanced Mix Design (BMD)

Issues and challenges and how BMD can help

February 2025

BATT

ASPHALT PAVEMENT ASSOCIATION OF WEST VIRGINIA

Today's Topics

- BATT
- Challenges
- Introduction to Balanced Mix Design
- IDEAL-CT Overview
- HWT Overview
- Mix Design Examples
- Q&A

BATT Team

Labs staffed with multiple and certified technicians

Phil Blankenship, MSCE, PE

Owner/Civil Engineer

32+ years experience (DOT, industry, research)

Zack McKay

Laboratory Operations Manager

12+ years experience in asphalt testing

Background

Blankenship Asphalt Tech & Training (BATT) boasts a team of asphalt **experts** with extensive experience dating back to the introduction of Superpave and volumetric mix designs in **1993**. Our services encompass a range knowledge from

Lab–to–Pavement

AASHTO **accredited**, the BATT Lab, offers a wealth of experience in product evaluations, development, field services and training tailored to specific needs in the asphalt industry.

BATT Lab

Forensics

Mix design & BMD

Binder formulation

DFT friction

FAA design

Consulting

Pavement design

Forensics

Expert witness

Field Services

Inspection

Coring

Density testing

Engineering support

Video PCI BATT Vision

Training

Technician basics

Asphalt binder

Mix design

BMD Into, 101, and deep dive

On-site or BATT

BATT – 6,000 sf facility

Performance / BMD Testing

Asphalt Binder Analysis

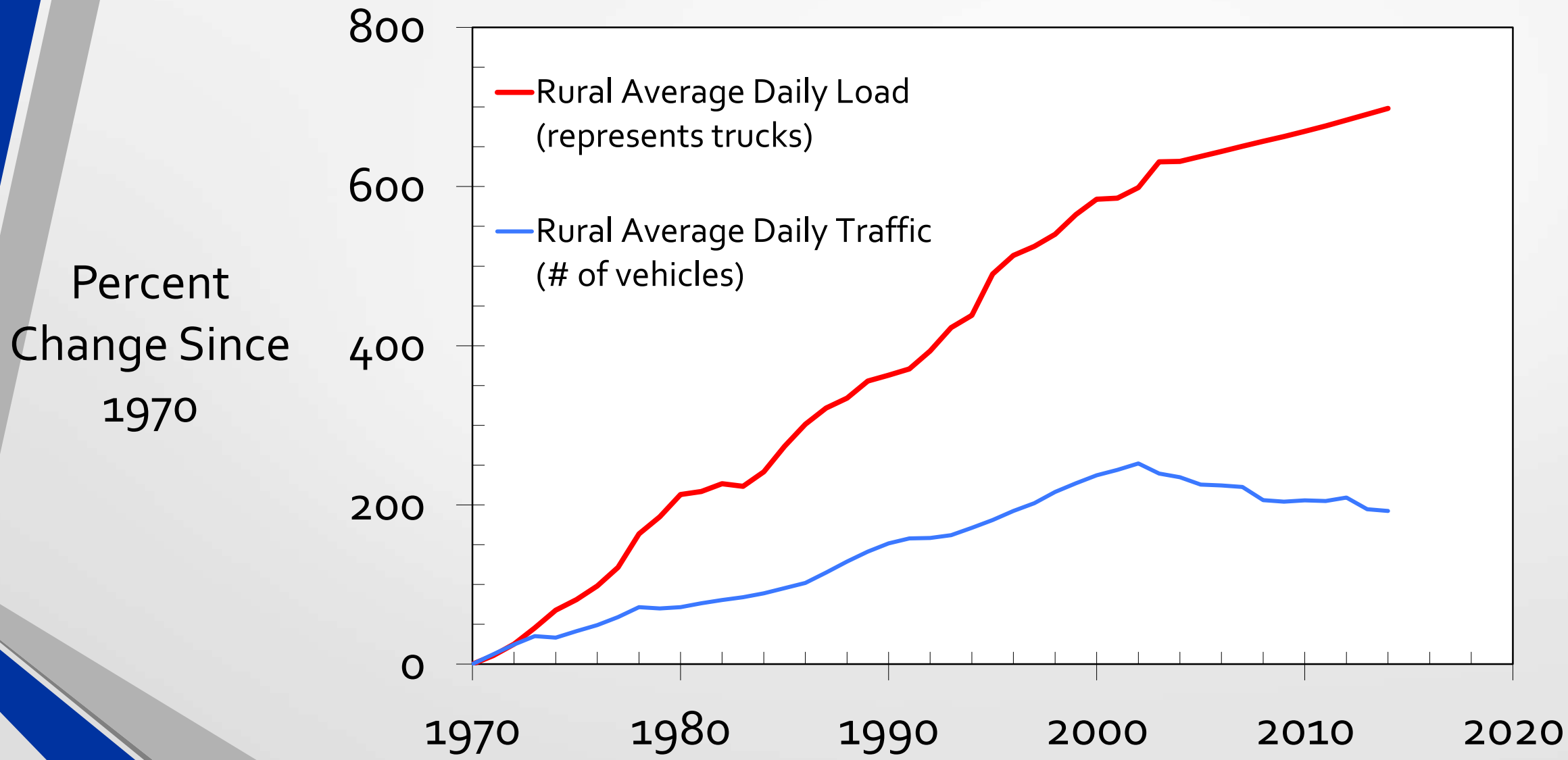
Pavement Forensics

Friction Testing

Custom Training

Challenges

Traffic & Load Growth on Rural Interstate System



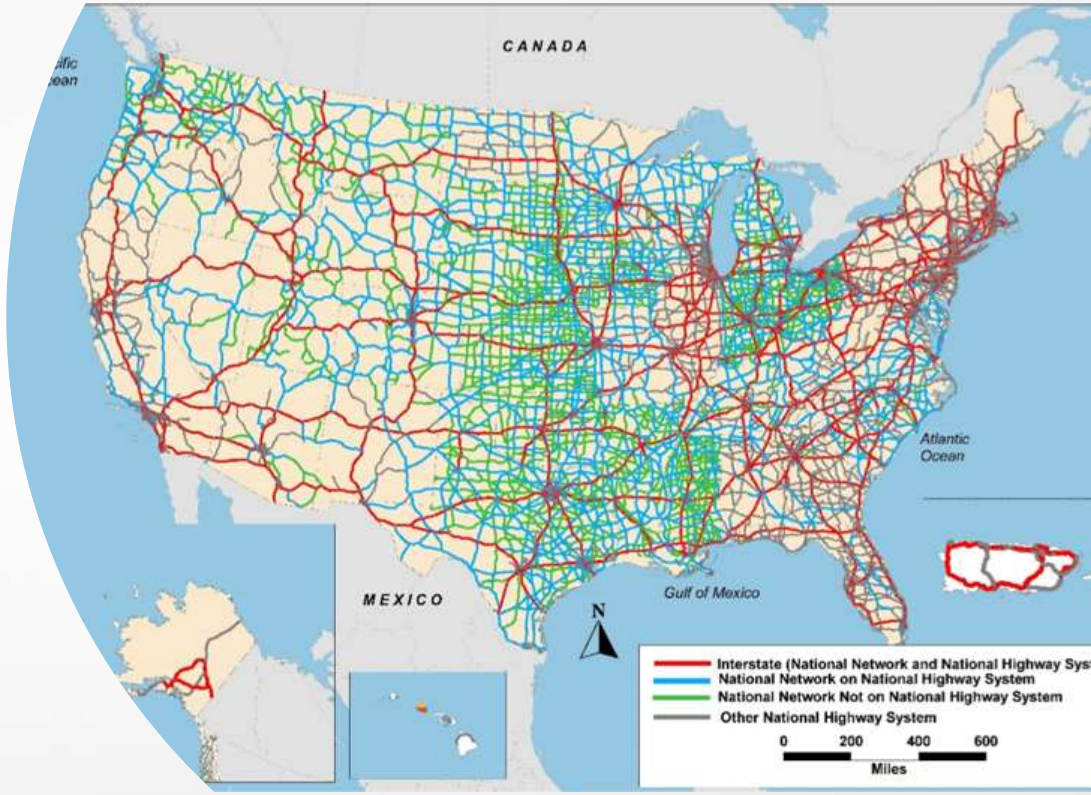
Source: FHWA Highway Statistics, Truck Weight Study

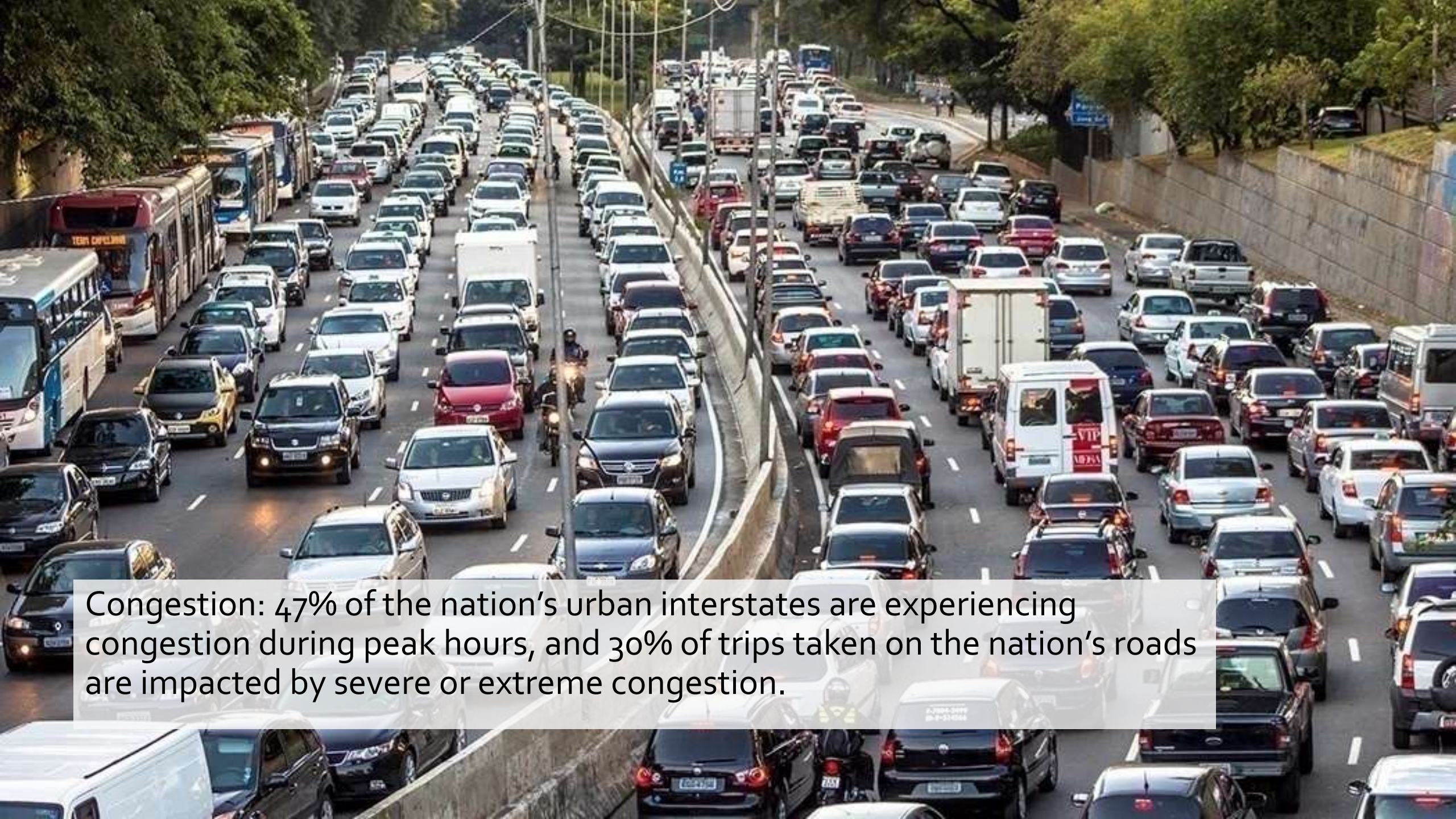
2021 ASCE Infrastructure Report Card

Source: https://www.infrastructurereportcard.org/

Facts

- 4 million miles of public roadways in the United States
- Our nation's highways and roads move 72%, or nearly $17 trillion, of the nation's goods
- Vehicle miles traveled reaching more than 3.2 trillion in 2019, an 18% increase from 2000
- Every lane-mile of road costs approximately $24,000 annually in operation and maintenance



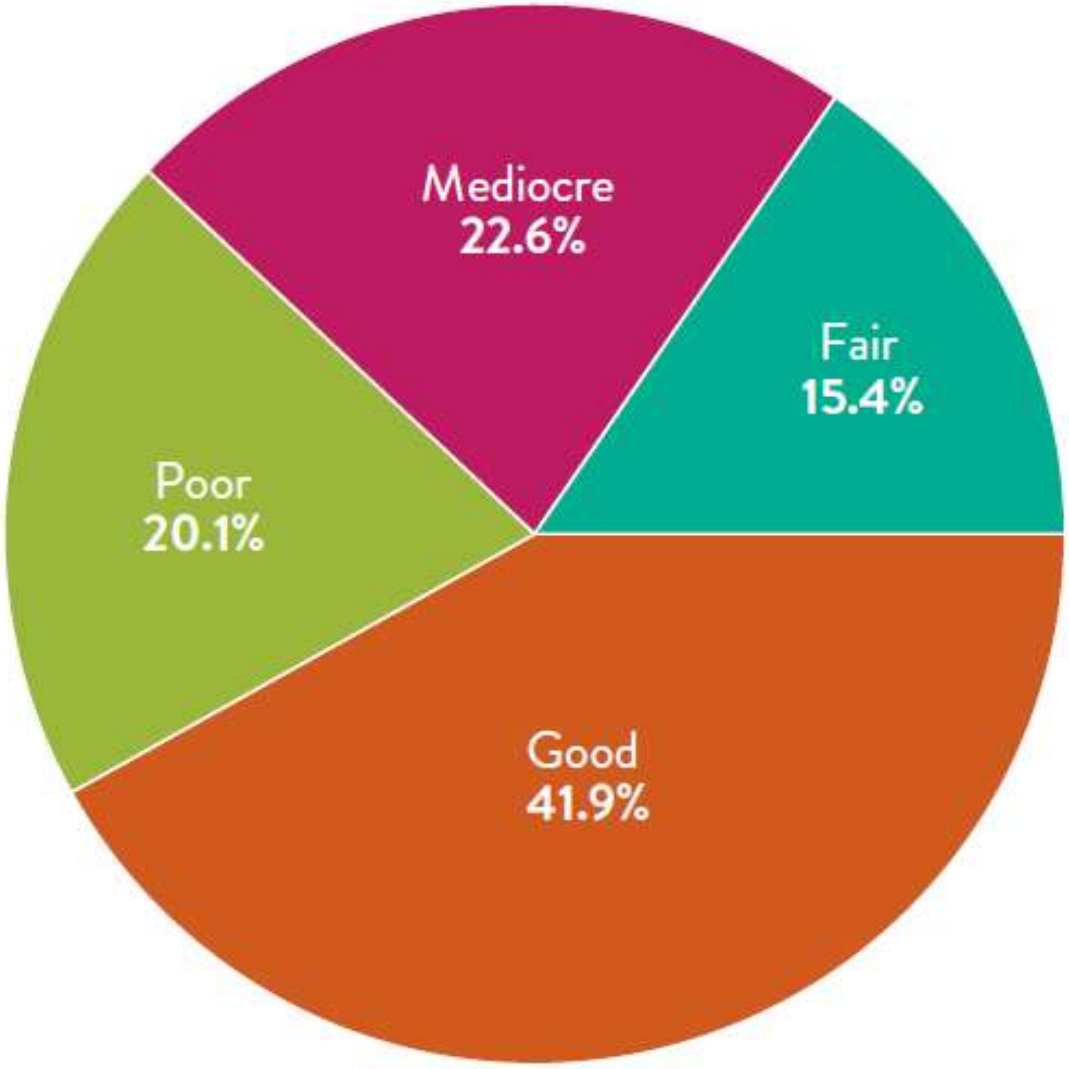


Congestion: 47% of the nation's urban interstates are experiencing congestion during peak hours, and 30% of trips taken on the nation's roads are impacted by severe or extreme congestion.

Condition

- **"D" rating** of our highway system
- **43%** of the system is now in poor or mediocre condition costing drivers an estimated $1000 annually
- While traffic fatalities have been on the decline, over **36,000 people are still dying** on the nation's roads every year
  - Number of pedestrian fatalities is on the rise
- At least **27 states have de-paved** roads.

Roadway Condition



Source: Data from TRIP, a National Transportation Research Nonprofit

Recommendations to Raise the Grade

- **Focus** resources on preserving a state of **good repair**
- **Increase funding** from **all** levels of government
- **Develop** state and local level comprehensive transportation asset management **plans**

Innovation

- Timely, preventive maintenance of our roads with better materials extends the life of pavement and costs less than reconstructing pavements after they reach failure
- Create smart pavements with sensors to provide real-time feedback with low user impact
- Additionally, the use of next generation materials and decentralized traffic lights to promote traffic flow
- See FHWA: https://www.fhwa.dot.gov/innovation/everydaycounts/edc-4.cfm

Sustainability

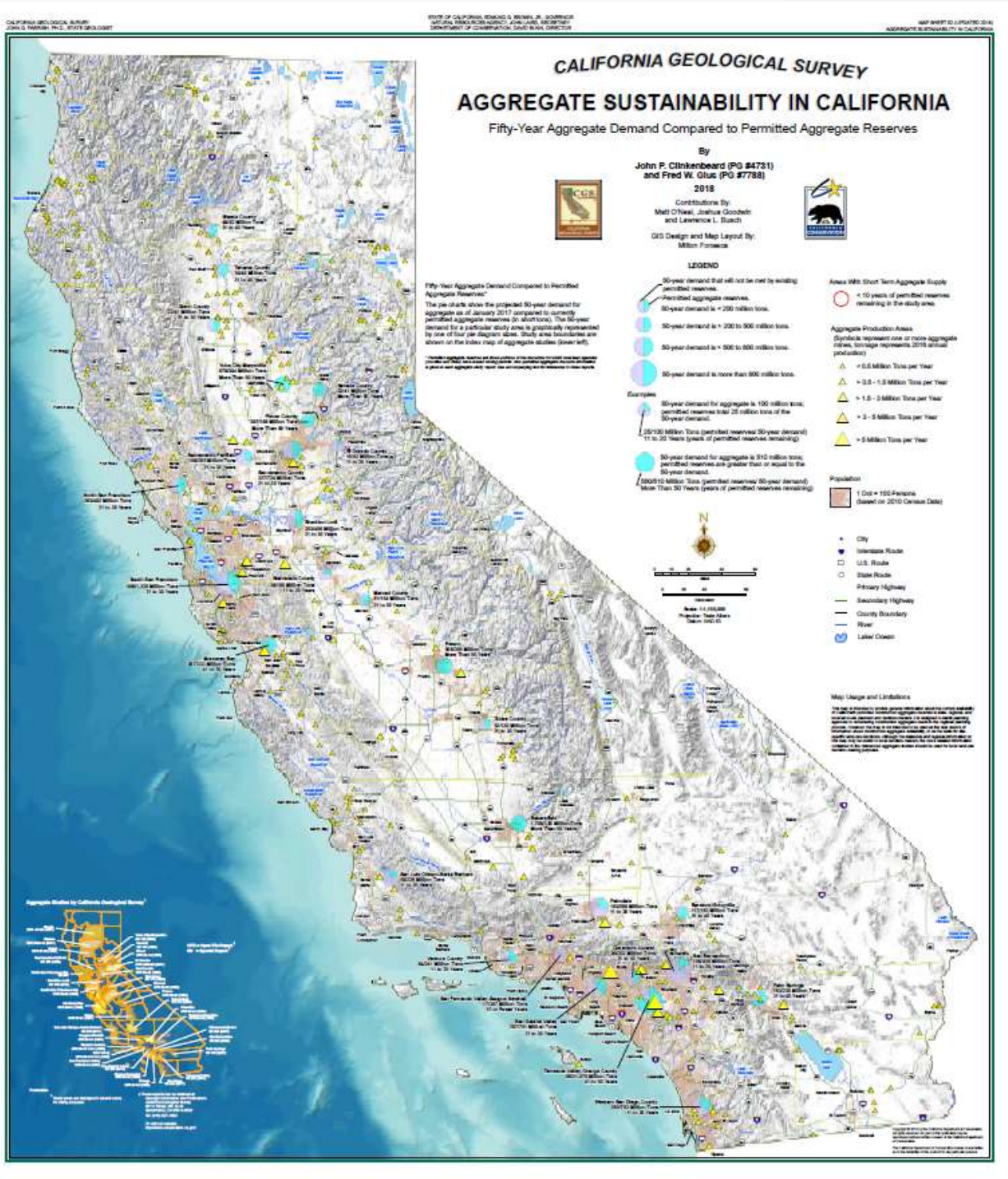
- Push to evaluate sustainable options
- Happening at a time we are trying to fix our mixes

Environmental Product Declaration (EDP)

https://www.fhwa.dot.gov/pavement/sustainability/hif21025.pdf

- Focus on meeting carbon neutral 2050 mandate
  - Reduce CO_2 levels
- Product Category Rules (PCR) and Life Cycle Assessment (LCA) inputs
- 3 scopes
  - Cradle to Gate
  - Cradle to Site
  - Cradle to Grave

Scarcity of New Aggregate Sources



Introduction

Balanced Mix Design

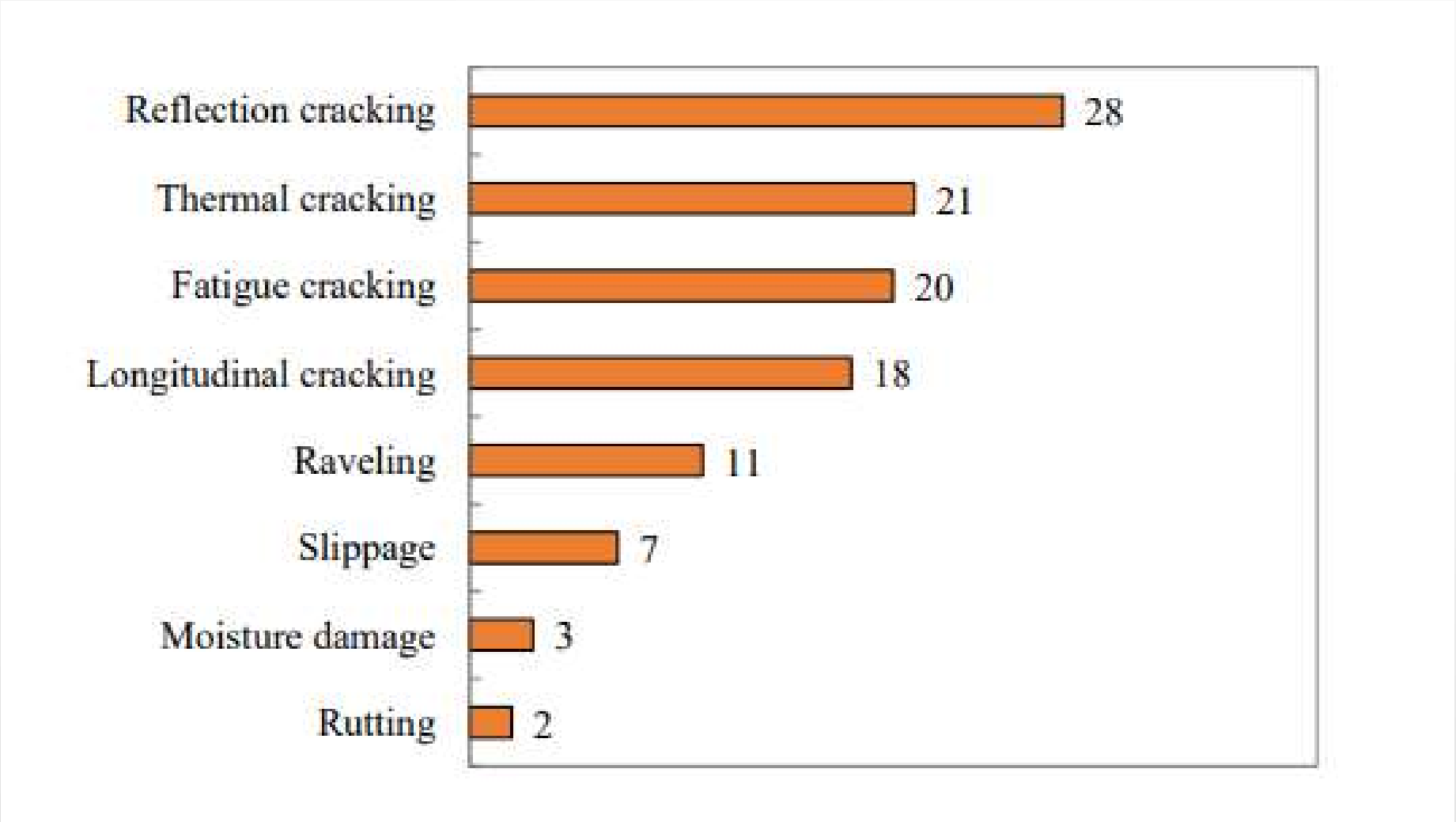
What is Balanced Mix Design

"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."

Need for BMD

- BMD is a balance between durability (cracking) and stability (rutting)
- Cracking of all types is most prevalent issue on US asphalt pavements (~2015 survey)
- Dry mixtures result in durability issues
- There is a need to understand the performance through performance-related testing

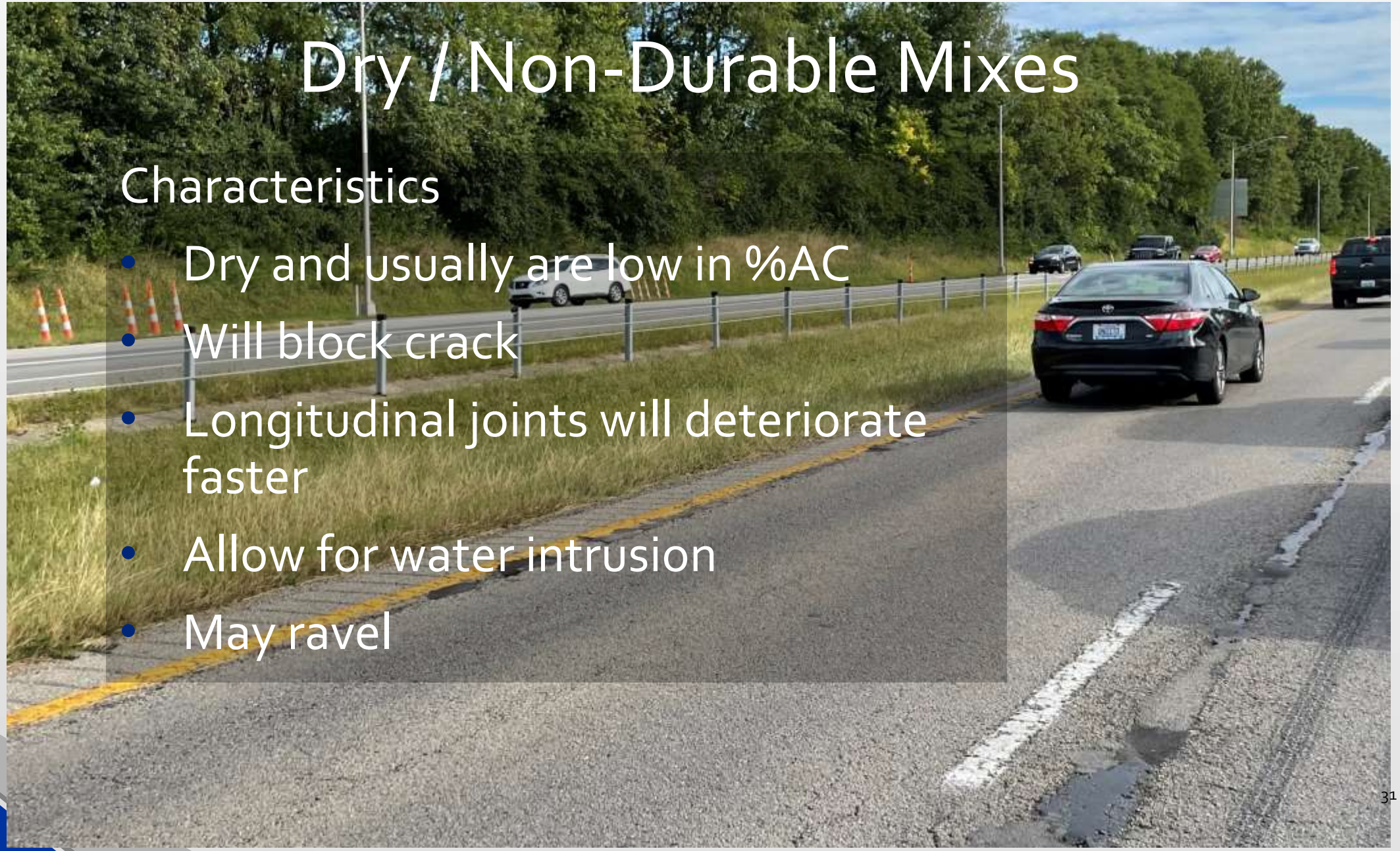
Pavement Distresses



Pavement Distresses reported by asphalt contractors

West, R. et al., Development of Framework for Balanced Mix Design

Dry / Non-Durable Mixes



Characteristics

- Dry and usually are low in %AC
- Will block crack
- Longitudinal joints will deteriorate faster
- Allow for water intrusion
- May ravel

Limitations of Volumetric Design

- Designs rely heavily on air voids (Va) and voids in mineral aggregate (VMA)
  - Establishes a minimum percent effective binder (Pbe)
- VMA is only as accurate as aggregate bulk gravities
  - Highly subjective tests
- Binder quality and effect of additives (positive or negative)
  - PPA, REOB, Rejuvenators
- Recycled products RAP and RAS
- Other additives
  - WMA, fibers, polymers, etc.

What Should Have Happened…

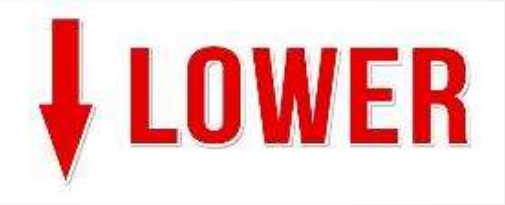
- Superpave called for Level 1, 2, and 3 testing based on traffic load
- Level 1 (Volumetrics + TSR) was only for up to around 1 million ESALS
- Level 2 and 3 were to be used for higher traffic loads and included rutting and cracking performance test
- Since we saw such good performance (with materials in 1993-2000), Levels 2 and 3 were soon forgotten…until now

Modifications to Superpave to Address Performance

To address cracking resistance in asphalt mixtures, numerous modifications have been made:

- Increase optimum asphalt content
  - Lowering Gyration Levels (N_{design})
  - Lowering Design Air Voids
- Polymer modification
- Recycled materials with blending charts
- Warm-Mix Asphalt (WMA)
- Balanced Mix Design (BMD)

Lowering Gyration Levels & Air Voids



- Superpave Gyratory Compactor (SGC) usually imparts higher compactive effort than seen in field
- Lowering gyration level achieves similar performance to field
  - Making this change is not likely to increase optimum AC without correction of the aggregate gradation
  - If not careful, dust can replace asphalt binder to fill voids
- Lower voids will increase optimum AC with constant VMA

Like a game of cat-mouse whereas BMD is what we are after

Why Change?

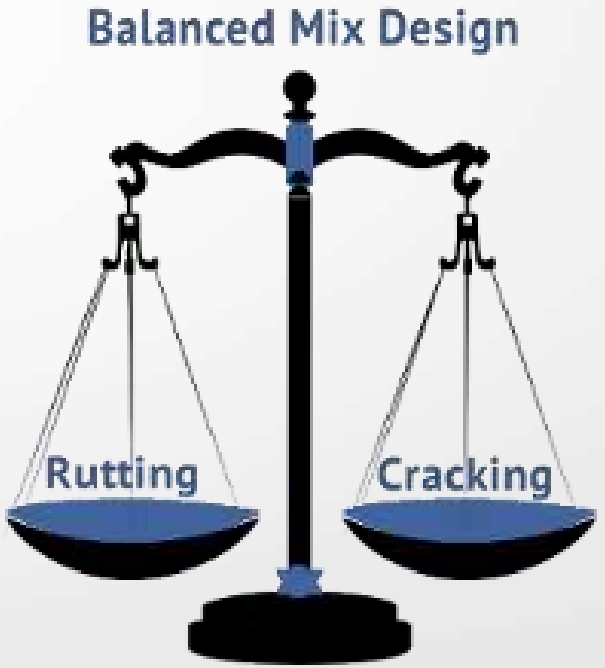
- Improving the service lives of asphalt pavements
- Eliminating premature failures of some asphalt
- Reducing the carbon footprint of asphalt pavements
- Optimizing asphalt mixtures for specific applications

BMD APPROACHES Randy West and Fan Yin, Special Report 228

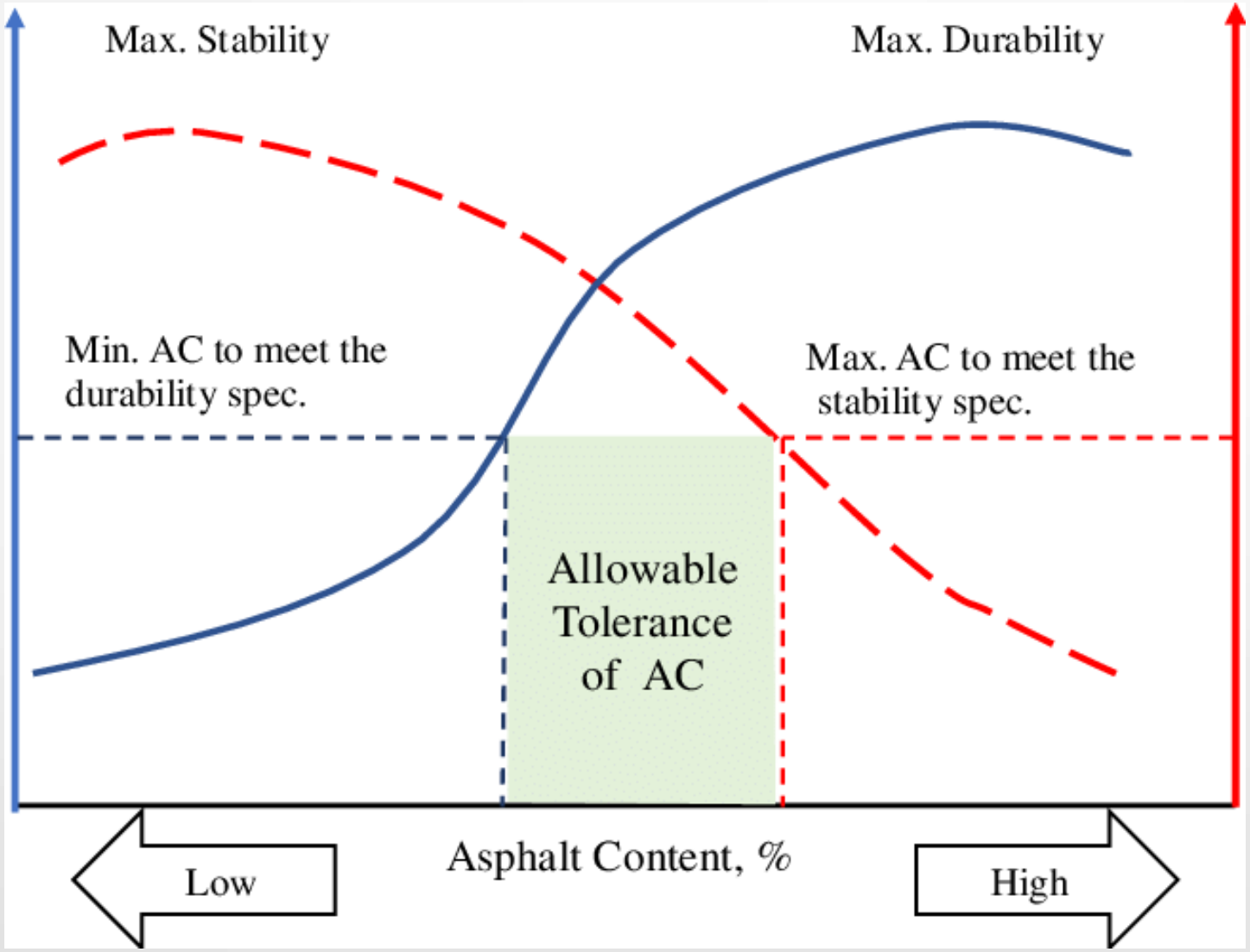
Also allows us to move beyond recipe specs and try new materials, cut costs, and increase RAP usage responsibly.

Balanced Mix Design

- Goes beyond simply analyzing the mix design volumetrics
  - Volumetrics do not indicate mixture performance but get us in the "ballpark"
- Estimates a mixture's performance to cracking resistance (durability) and rutting resistance (stability)…**the real goal**



The Plan



NCHRP 20-07/Task 406 Development of a Framework for Balanced Mix Design (Haydar Al-Khayat)

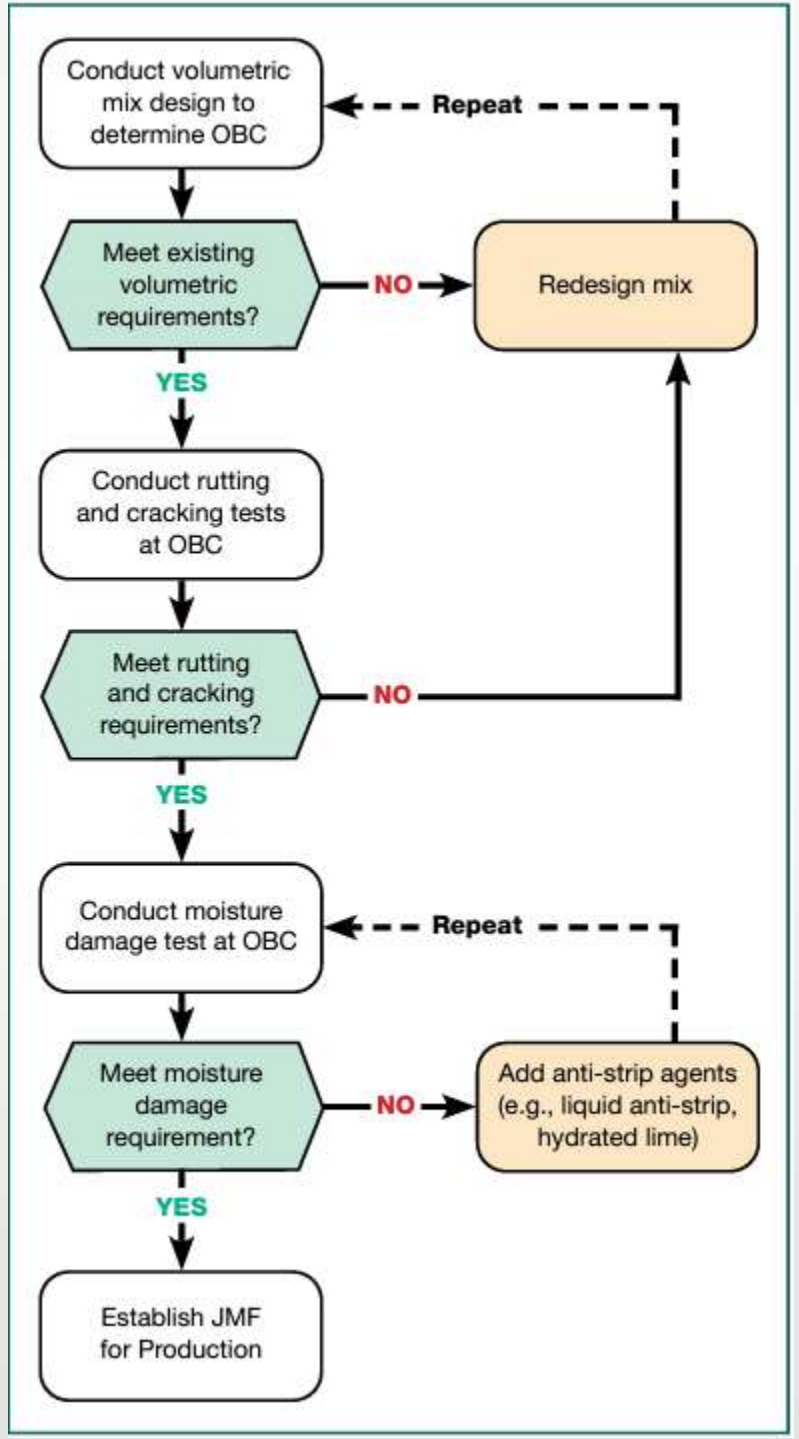
BMD Approaches

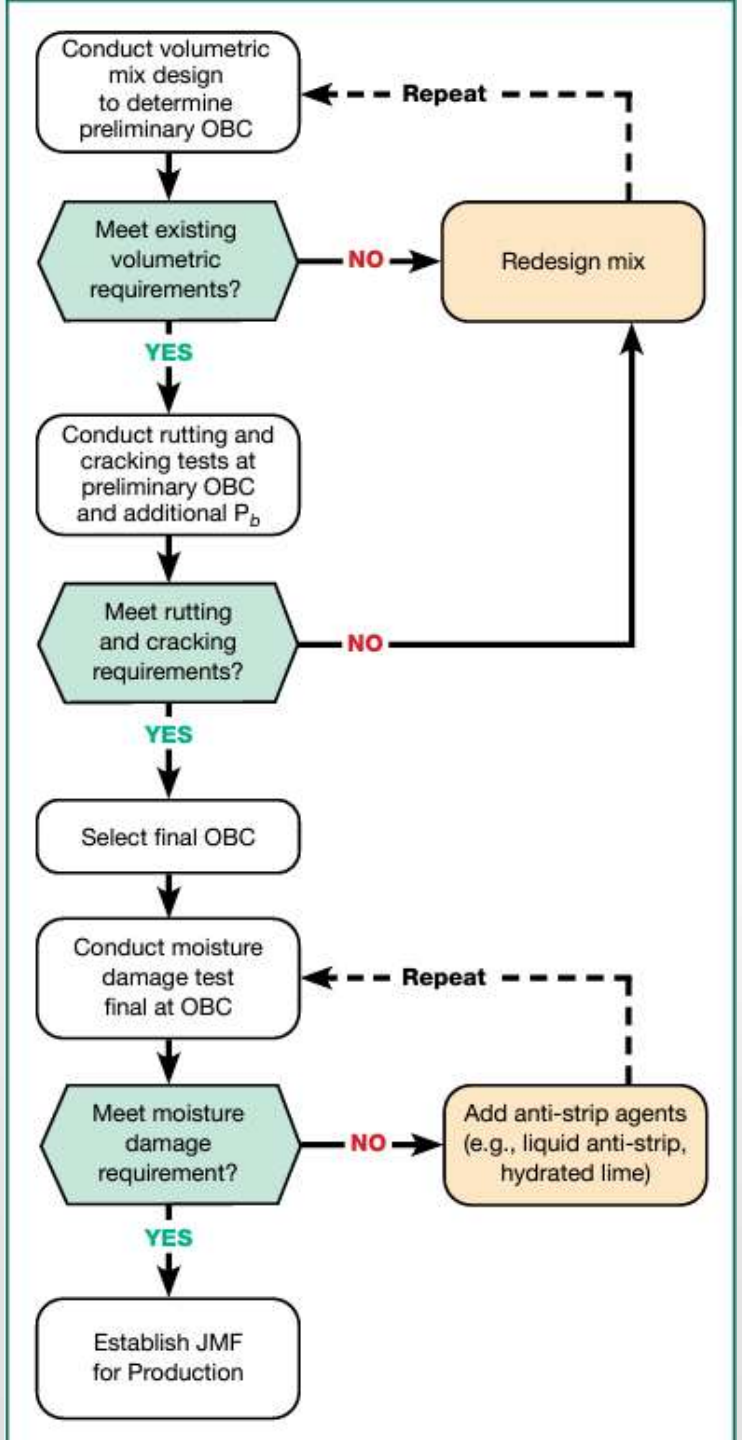
- A – Volumetric Design with Performance Verification
- B – Volumetric Design with Performance Optimization
- C – Performance-Modified Volumetric Design
- D – Performance Design

Approach: A

Volumetric Design with Performance Verification

OBC=optimum binder content



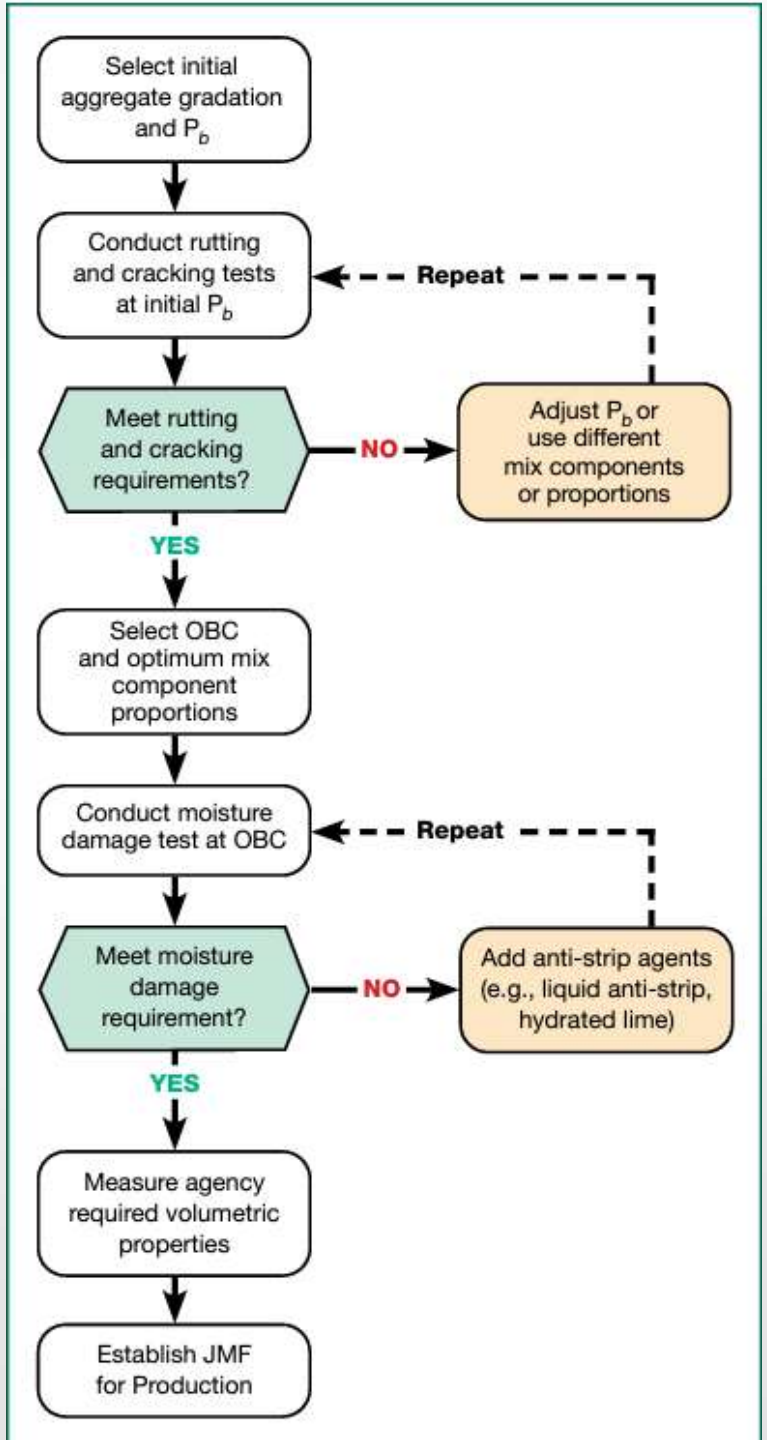


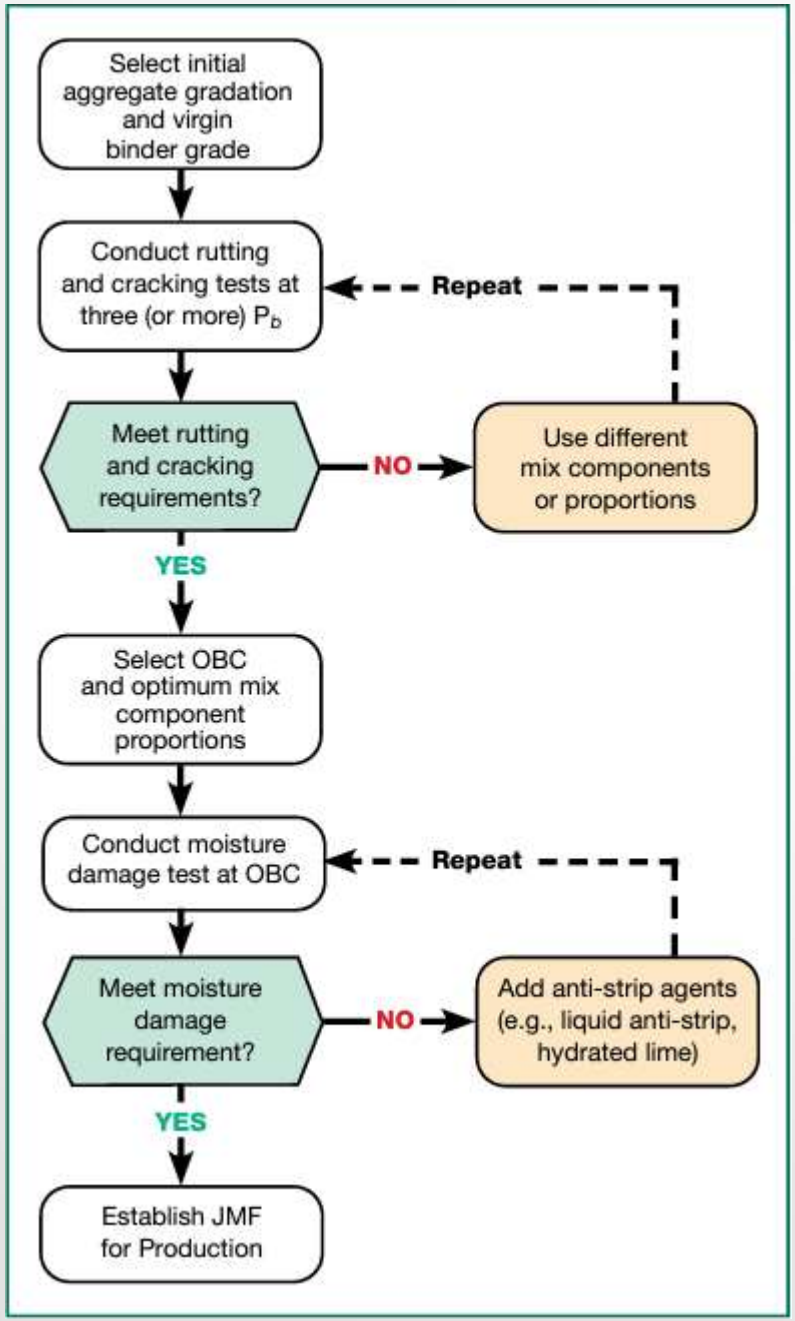
Approach: B

Volumetric Design with Performance Optimization

Approach: C

Performance-Modified Volumetric Design





Approach: B

Performance Design (only)

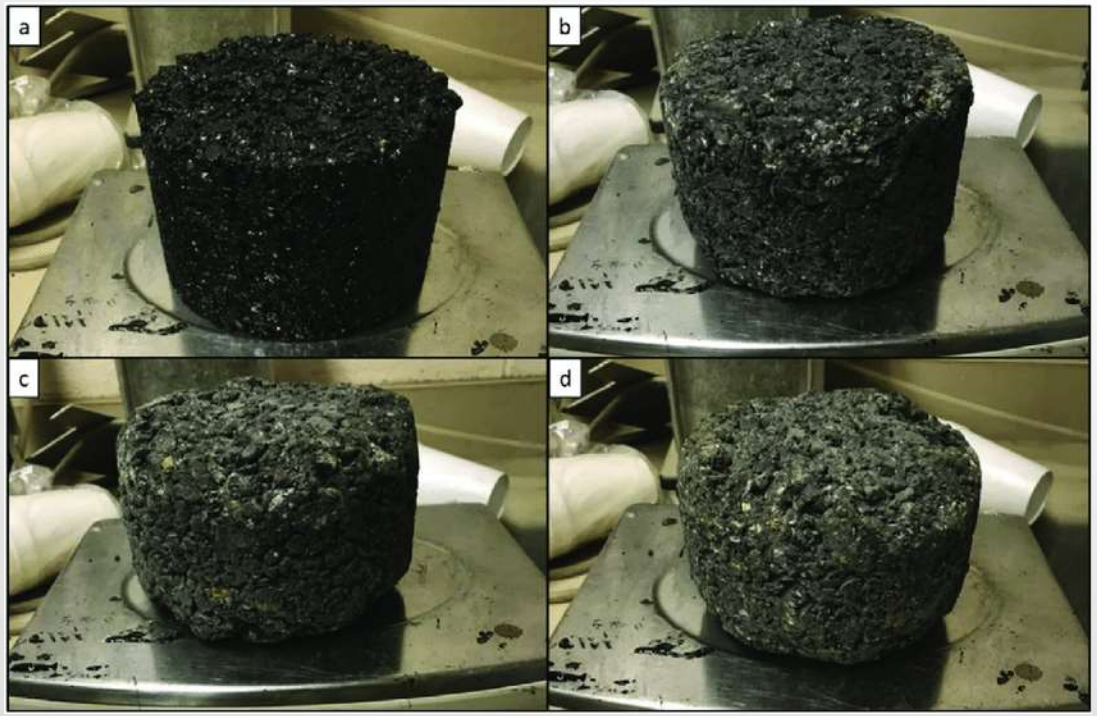
What Tests Are Available?

Rutting

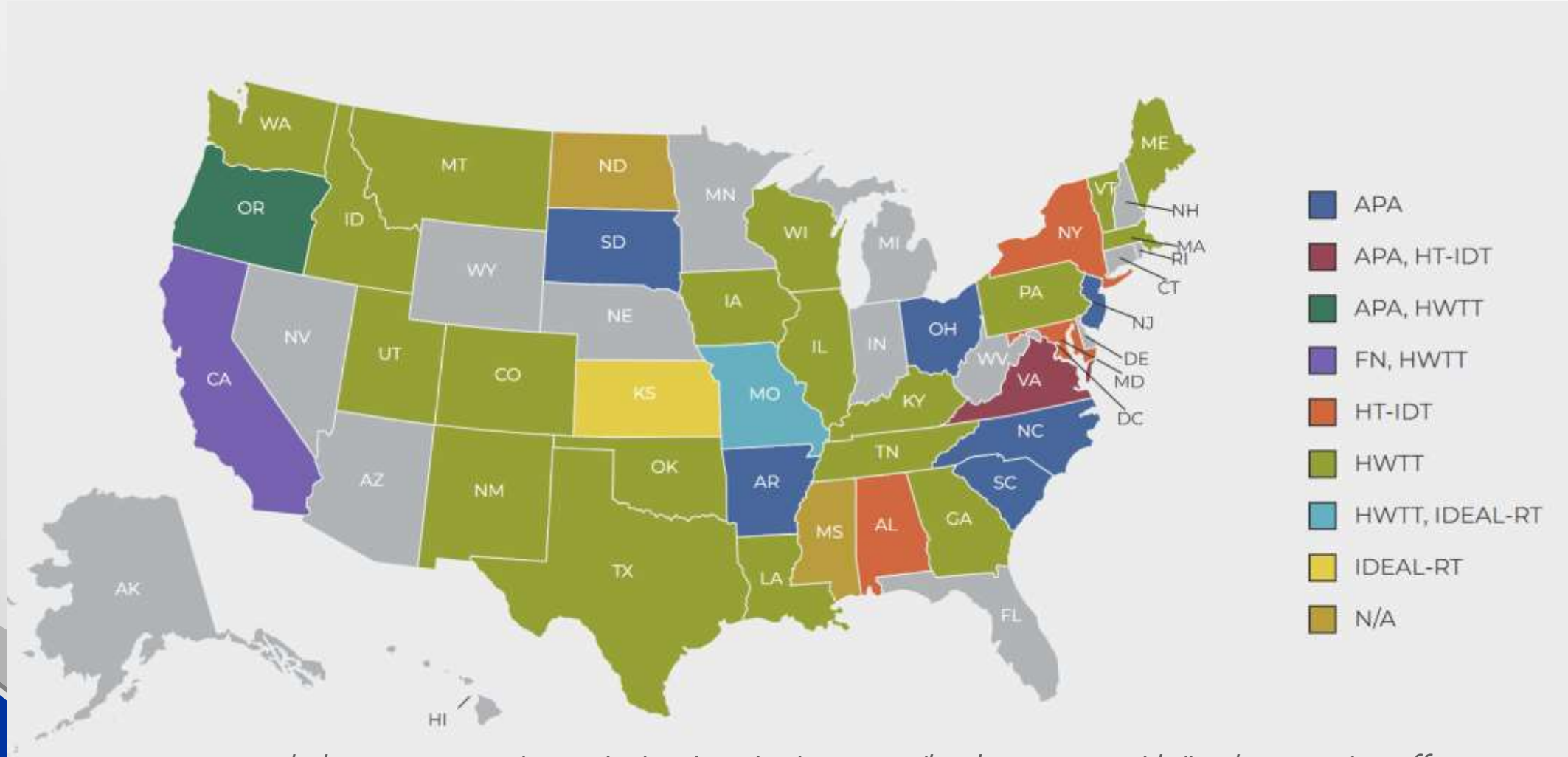
- Hamburg Wheel Tracker (HWT)
- Asphalt Pavement Analyzer (APA)
- AMPT Flow Number (FN)
- IDEAL-RT
- HT-IDT

General Durability / Adhesion

- Cantabro – good general proof test

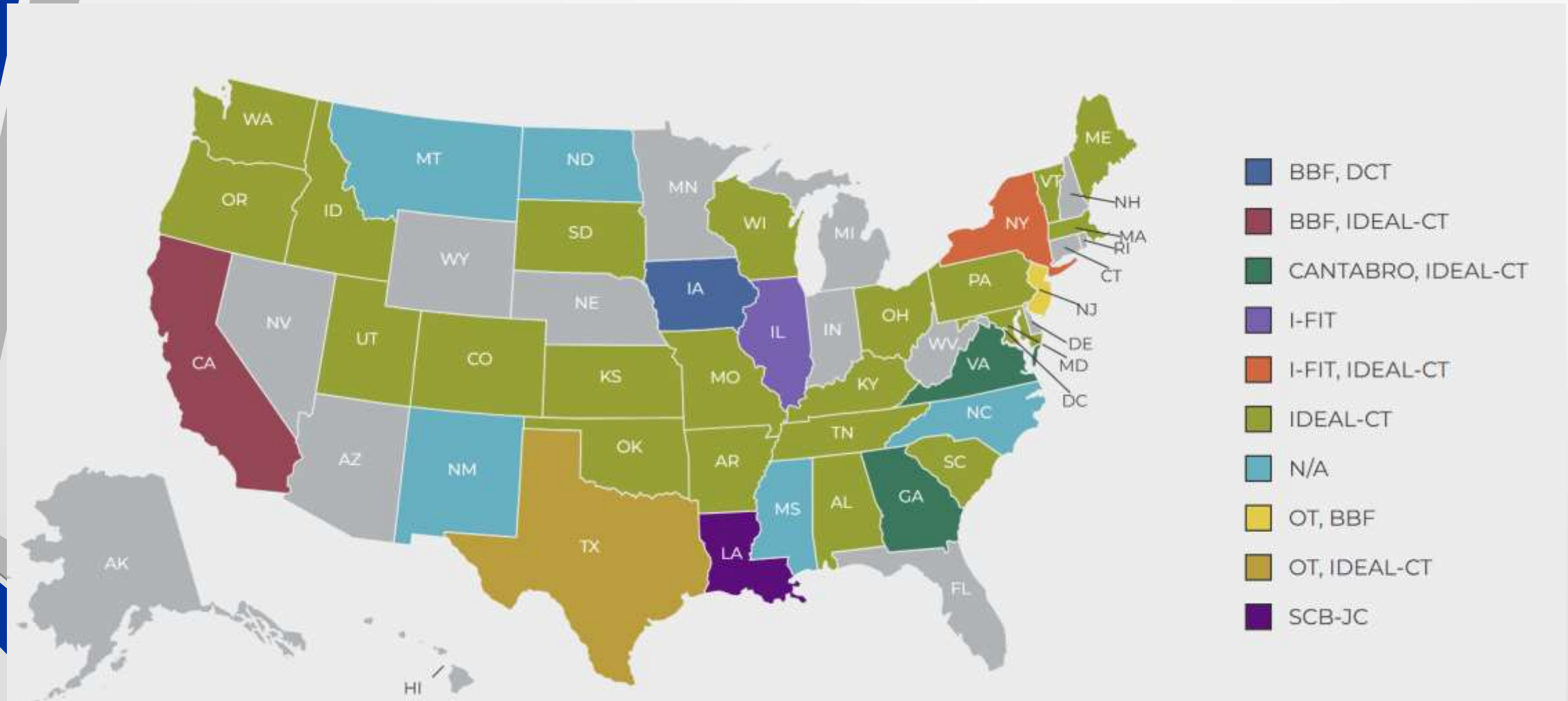


Rutting Test Adoption



www.asphaltpavement.org/expertise/engineering/resources/bmd-resource-guide/implementation-efforts

Cracking Test Adoption



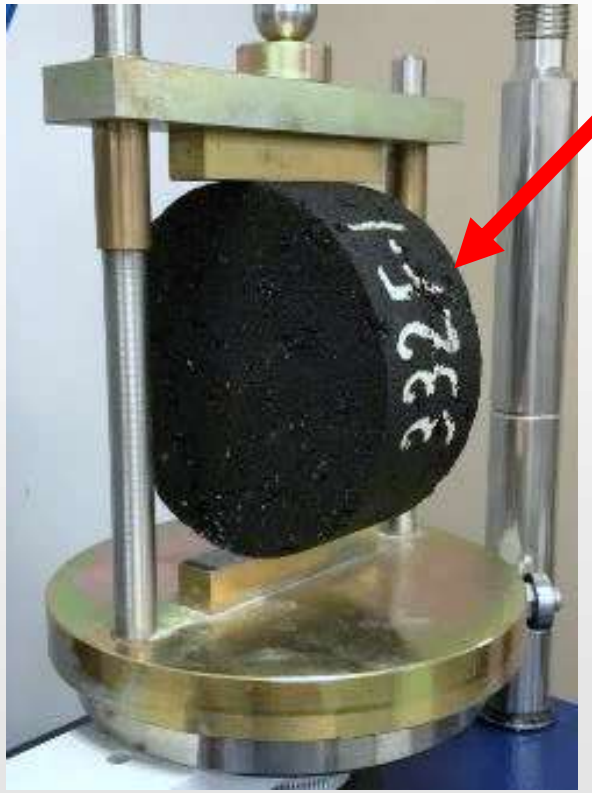
www.asphaltpavement.org/expertise/engineering/resources/bmd-resource-guide/implementation-efforts

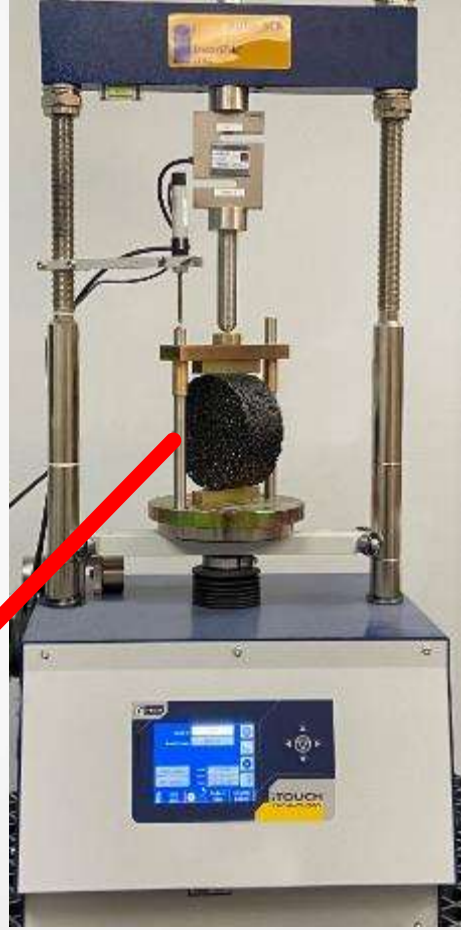
IDEAL-CT Test Overview

Balanced Mix Design

IDEAL-CT (ASTM 8225)

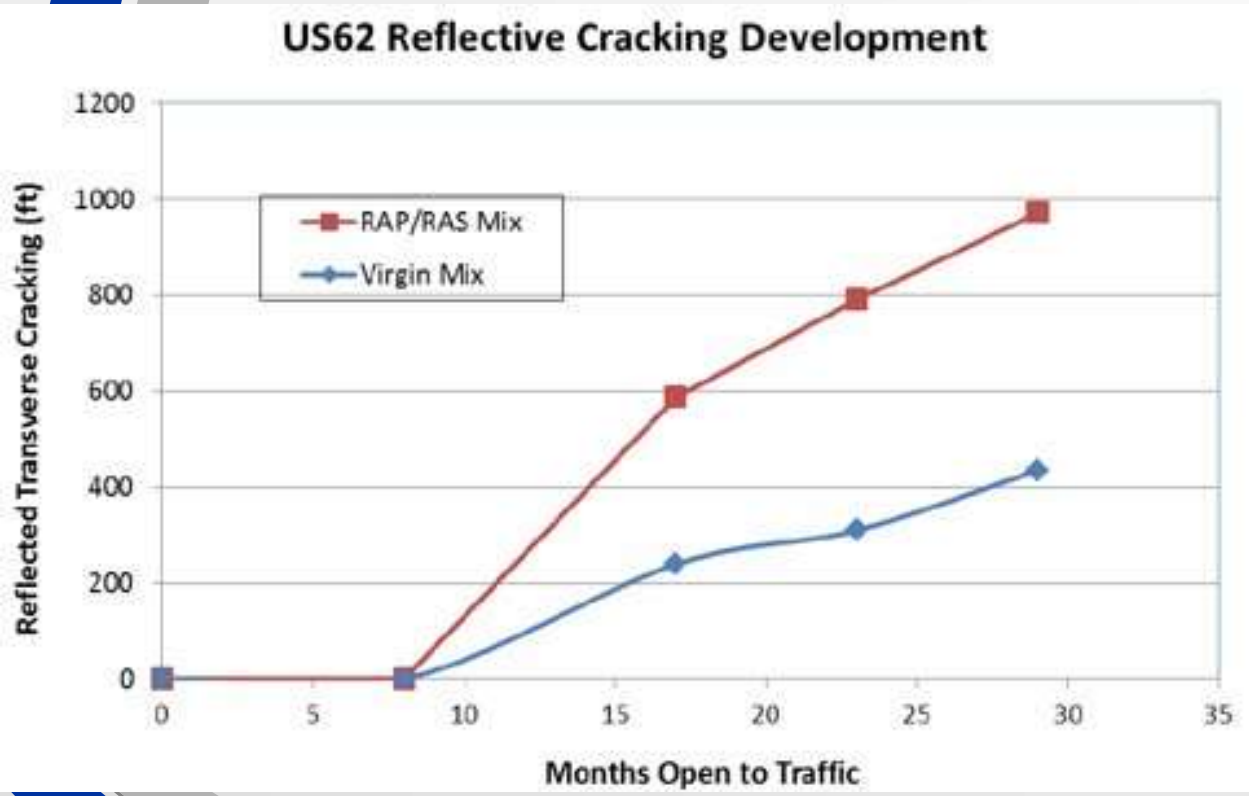
- Officially named: ***I**n**d**irect T**e**nsile **A**sphalt **C**racking **T**est*
- Simple way to measure the cracking potential of asphalt mixtures

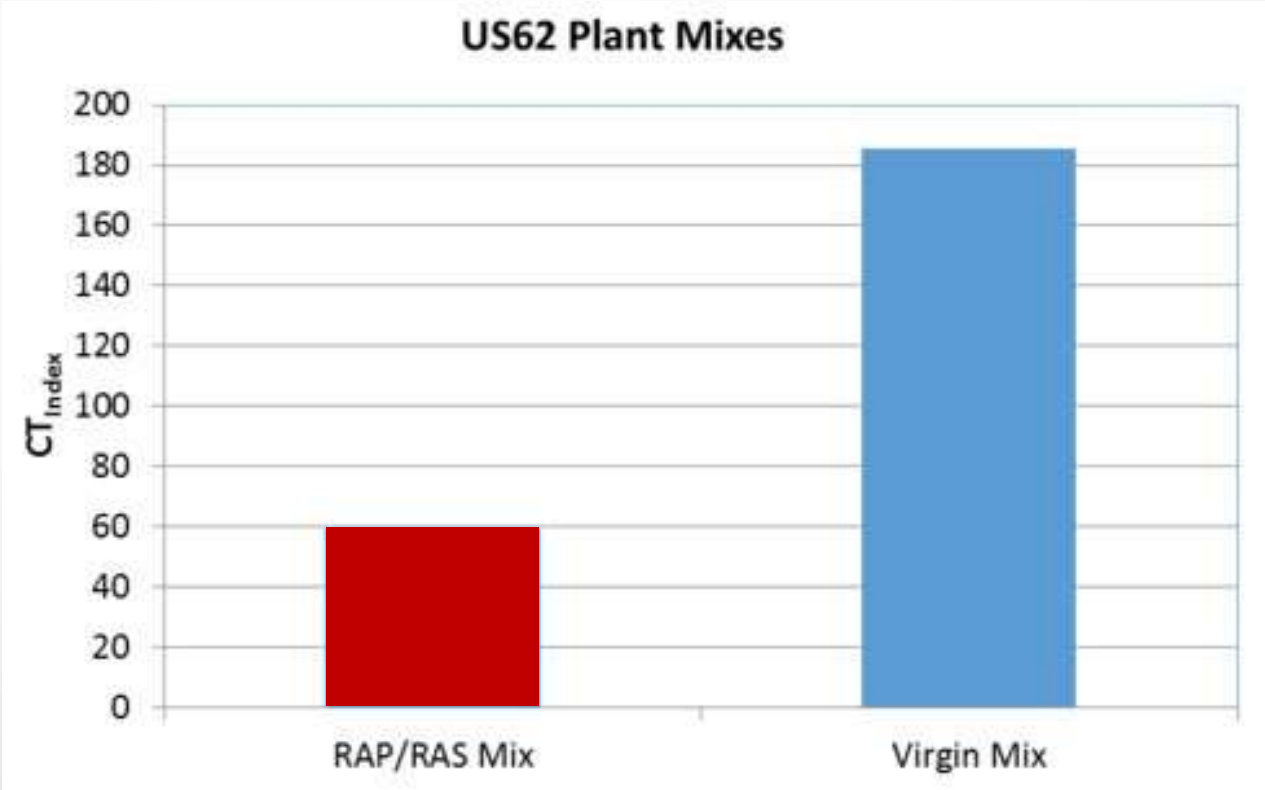




Correlation with Field Performance

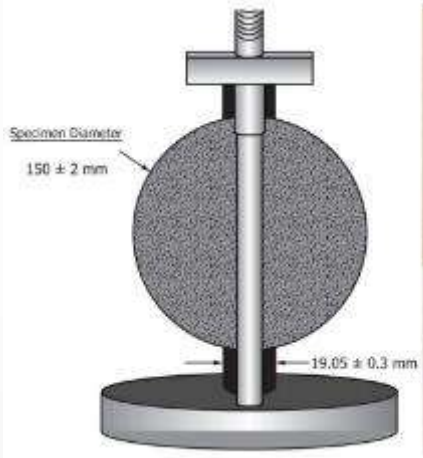
Higher cracking in field = lower CT index





Zhou, F et al., Development of an IDEAL Cracking Test for Asphalt Mix Design and QC/QA, Texas A&M Transportation Institute (TTI)

Test Equipment

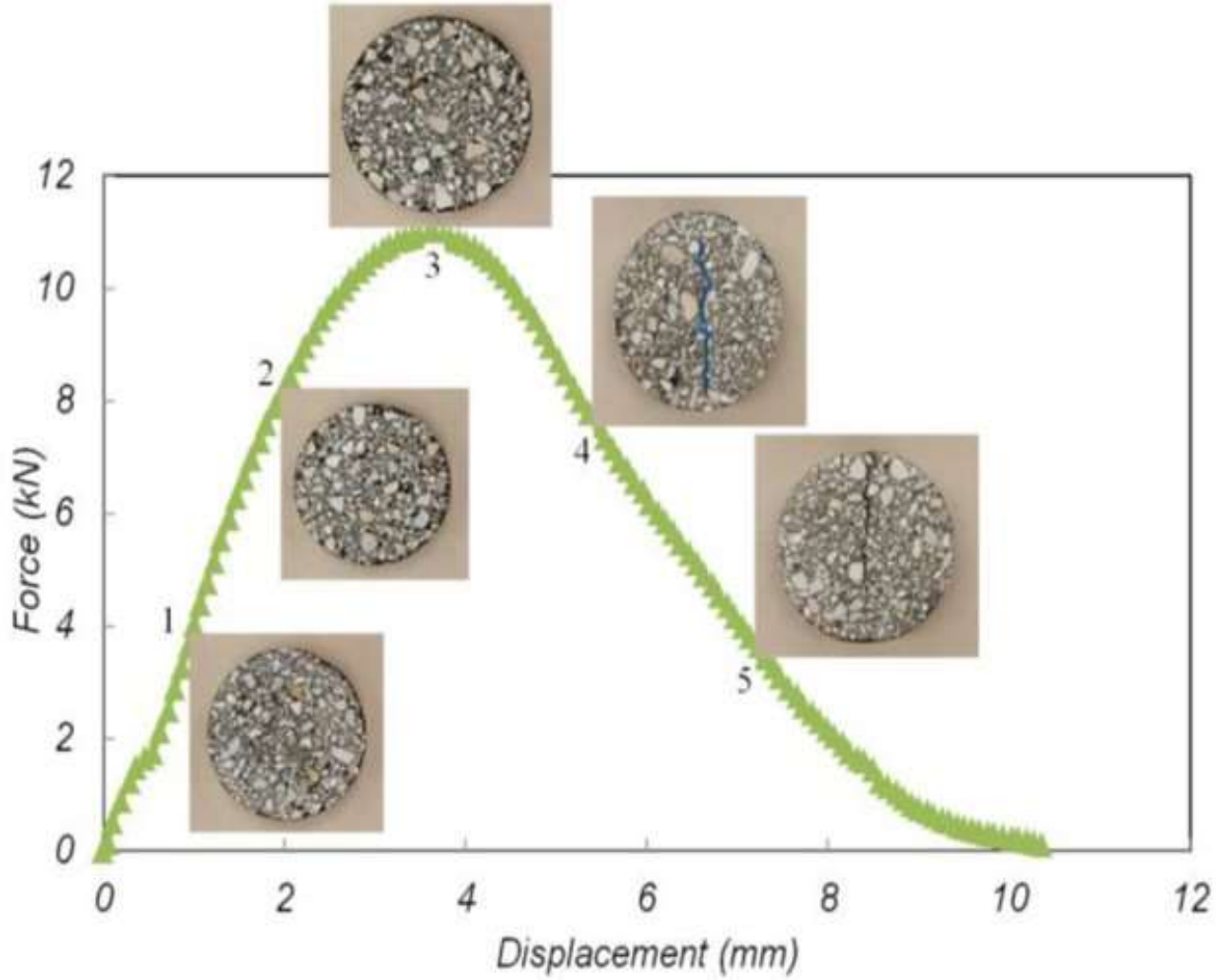


IDEAL-CT Background

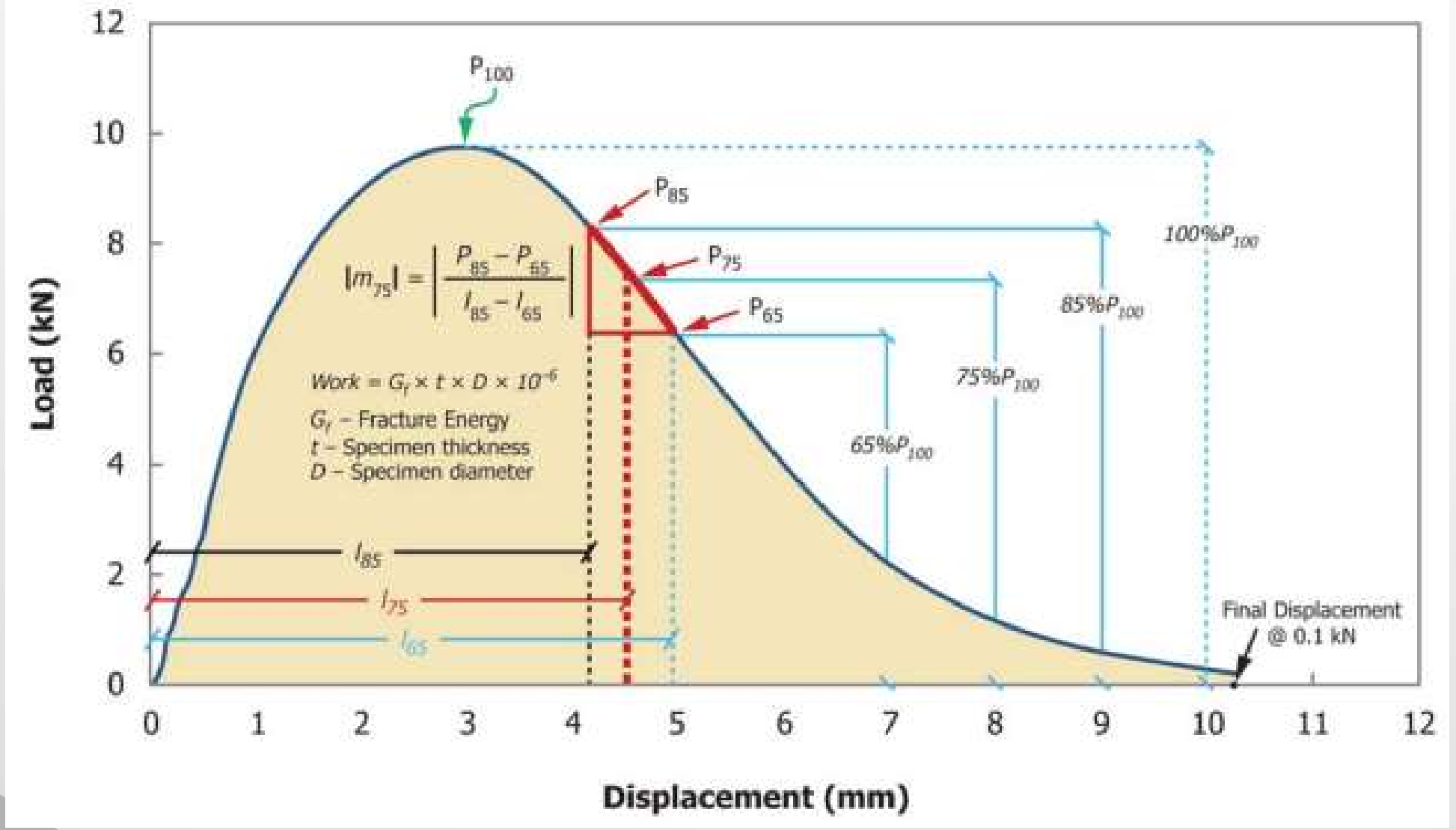
Test temperature: 25 ℃

Loading rate: 50mm/min.

Specimen: cylindrical specimen without cutting, gluing, instrumentation, drilling, and notching.

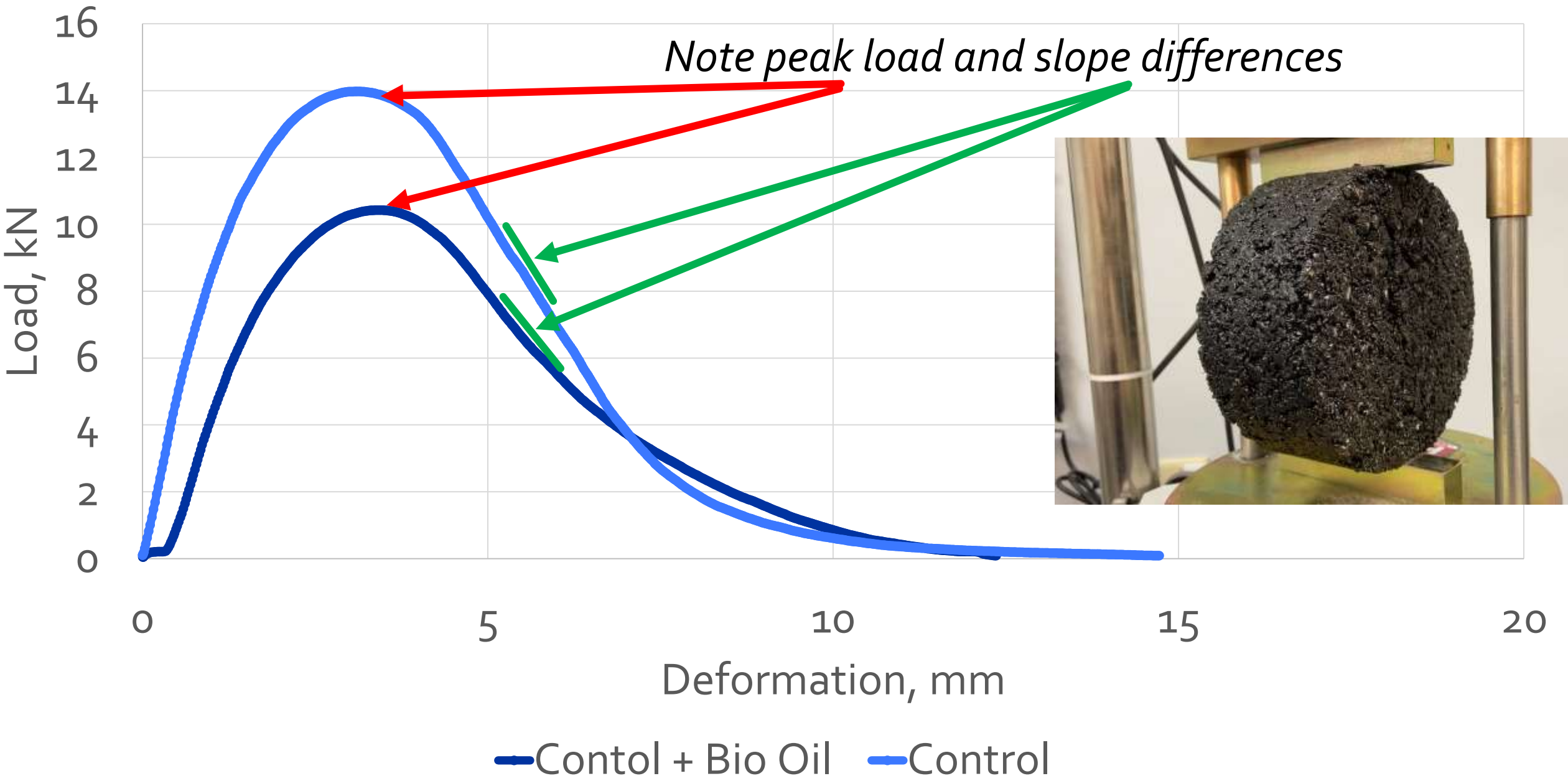


Typical Load-Line Displacement Curve

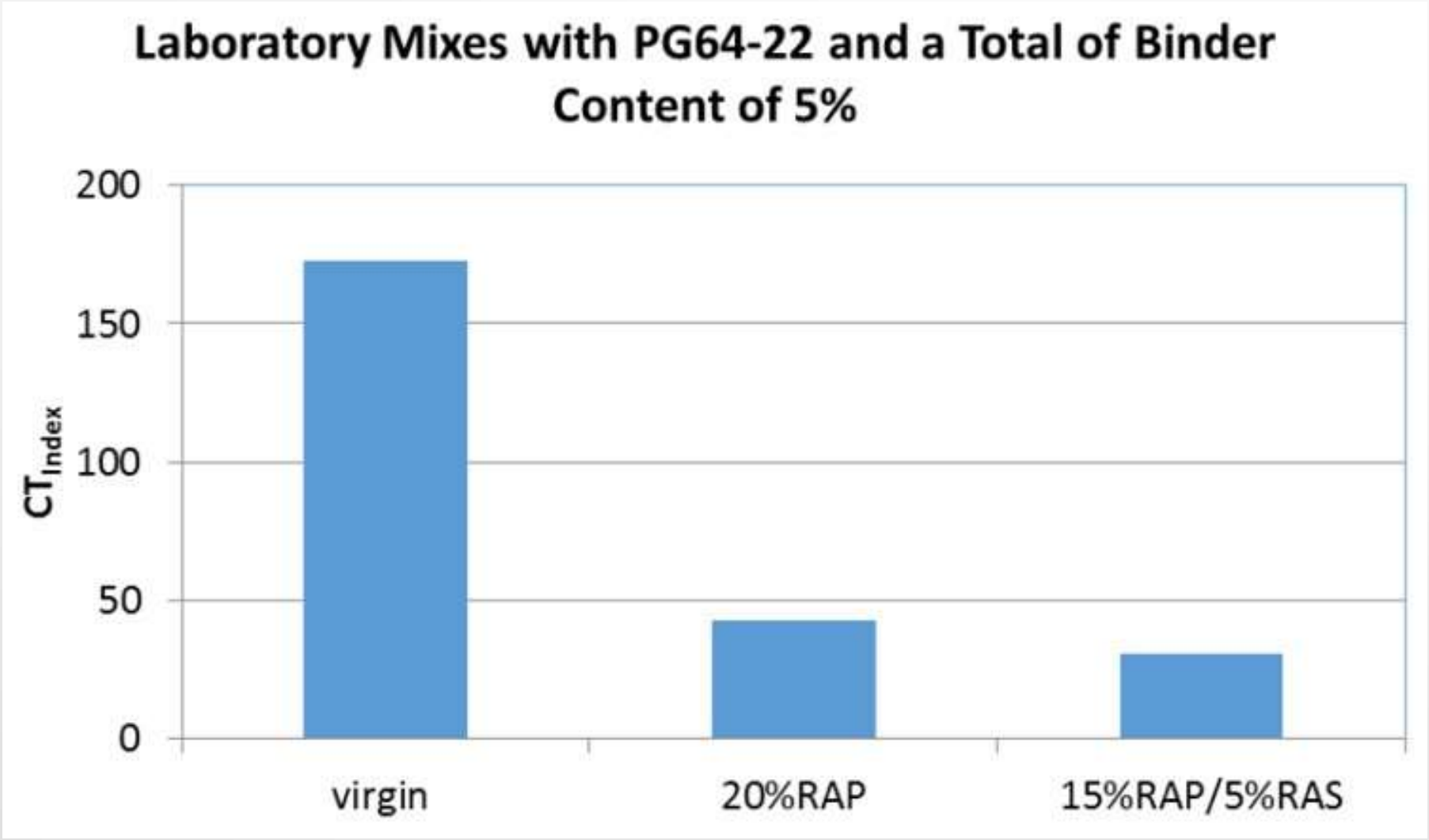


ASTM Standard D8225, 2019, Fig. 1, ASTM International, www.astm.org

Example IDEAL-CT Data Trace



IDEAL-CT Sensitivity to RAP/RAS



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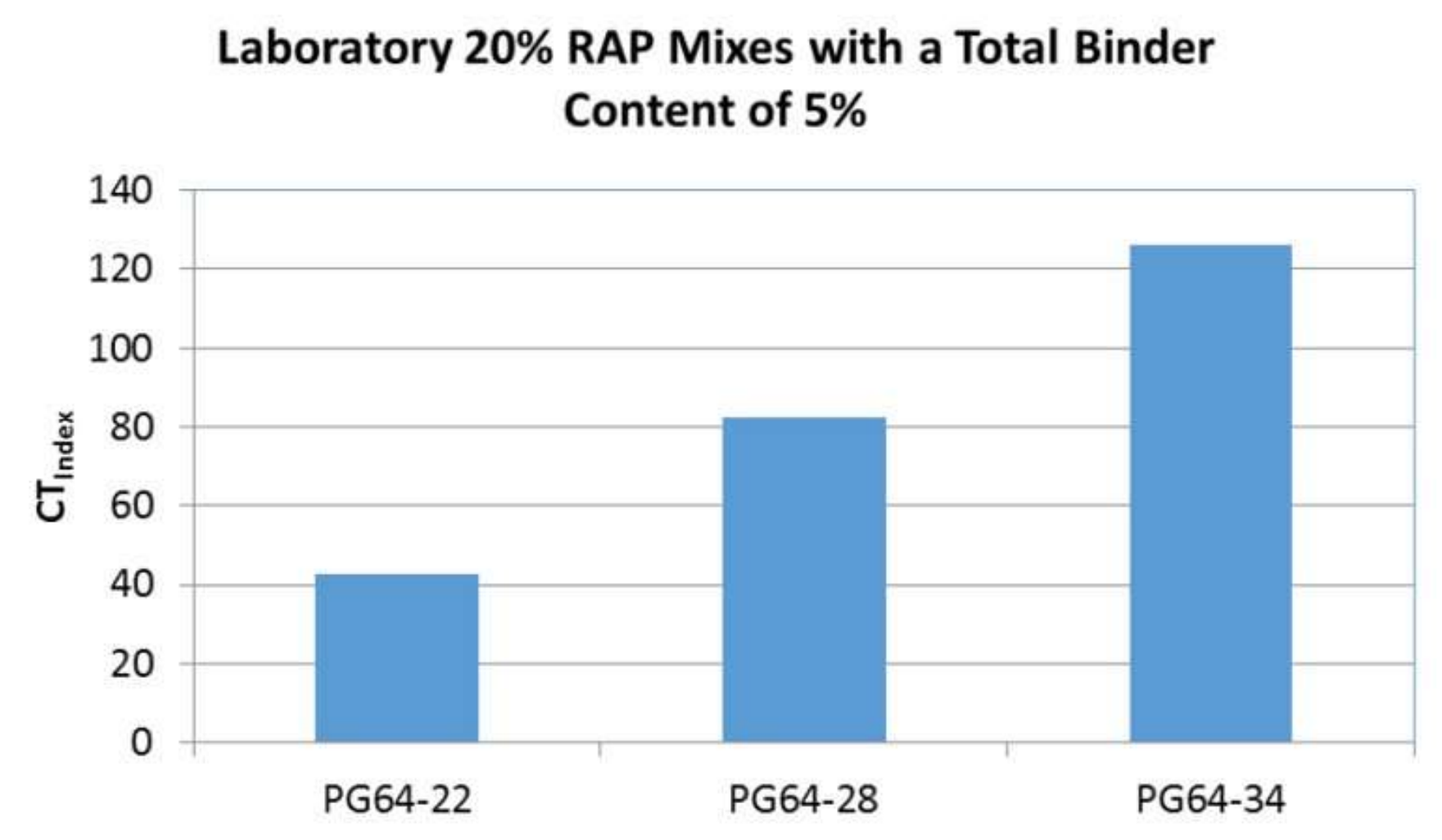
IDEAL-CT Sensitivity to Binder Type



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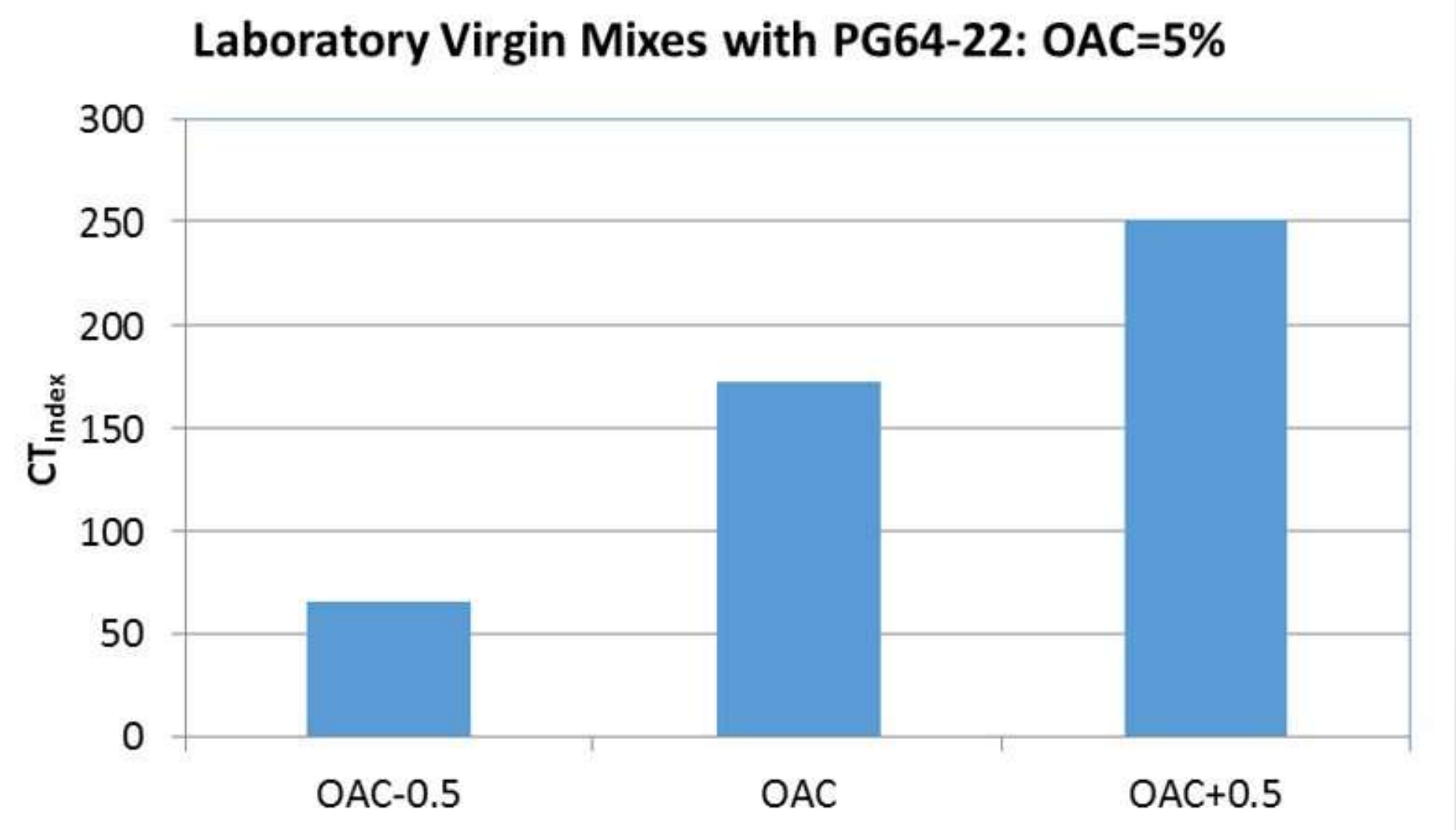
IDEAL-CT Sensitivity to Binder Content



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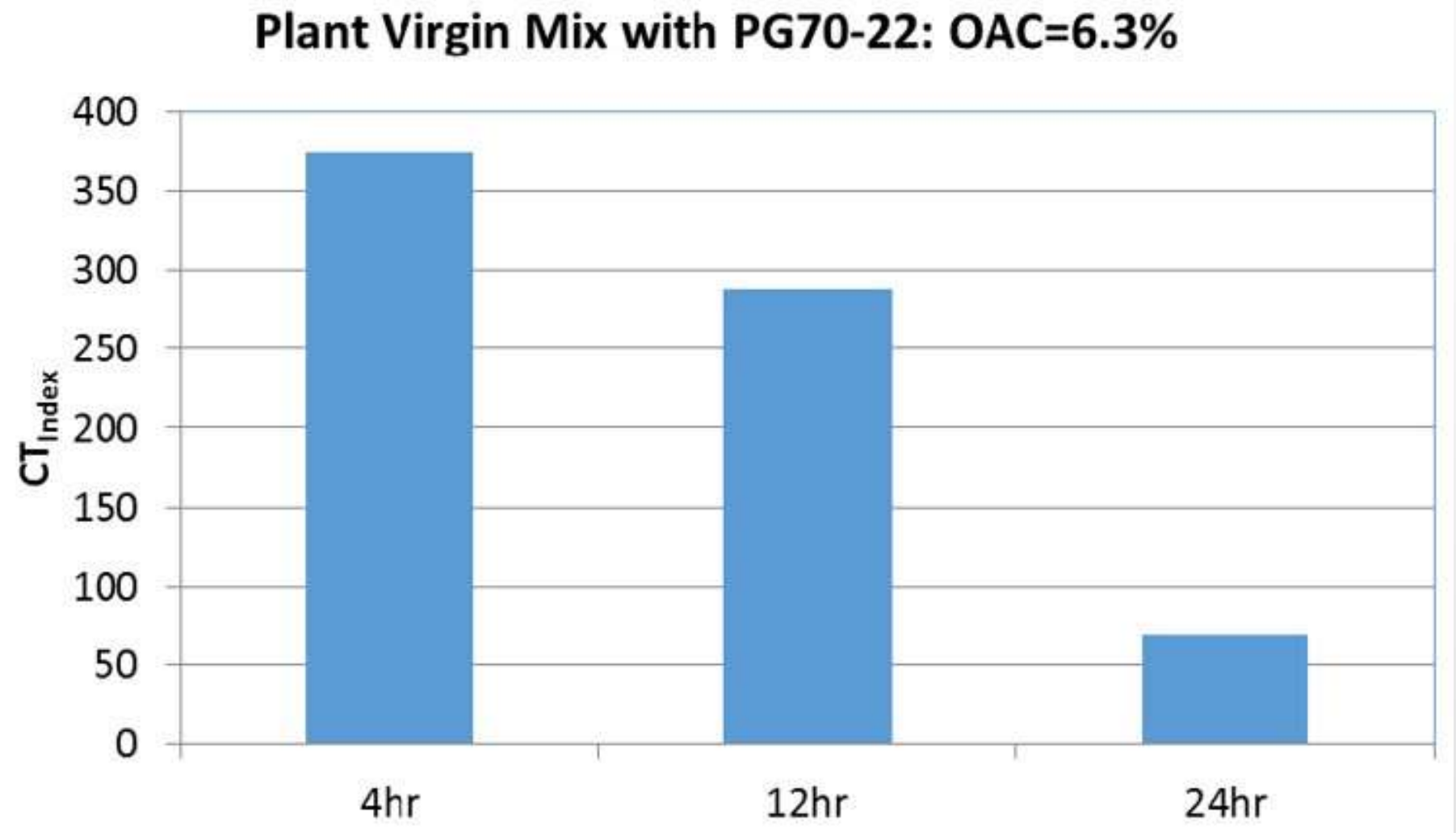
IDEAL-CT Sensitivity to Mix Aging



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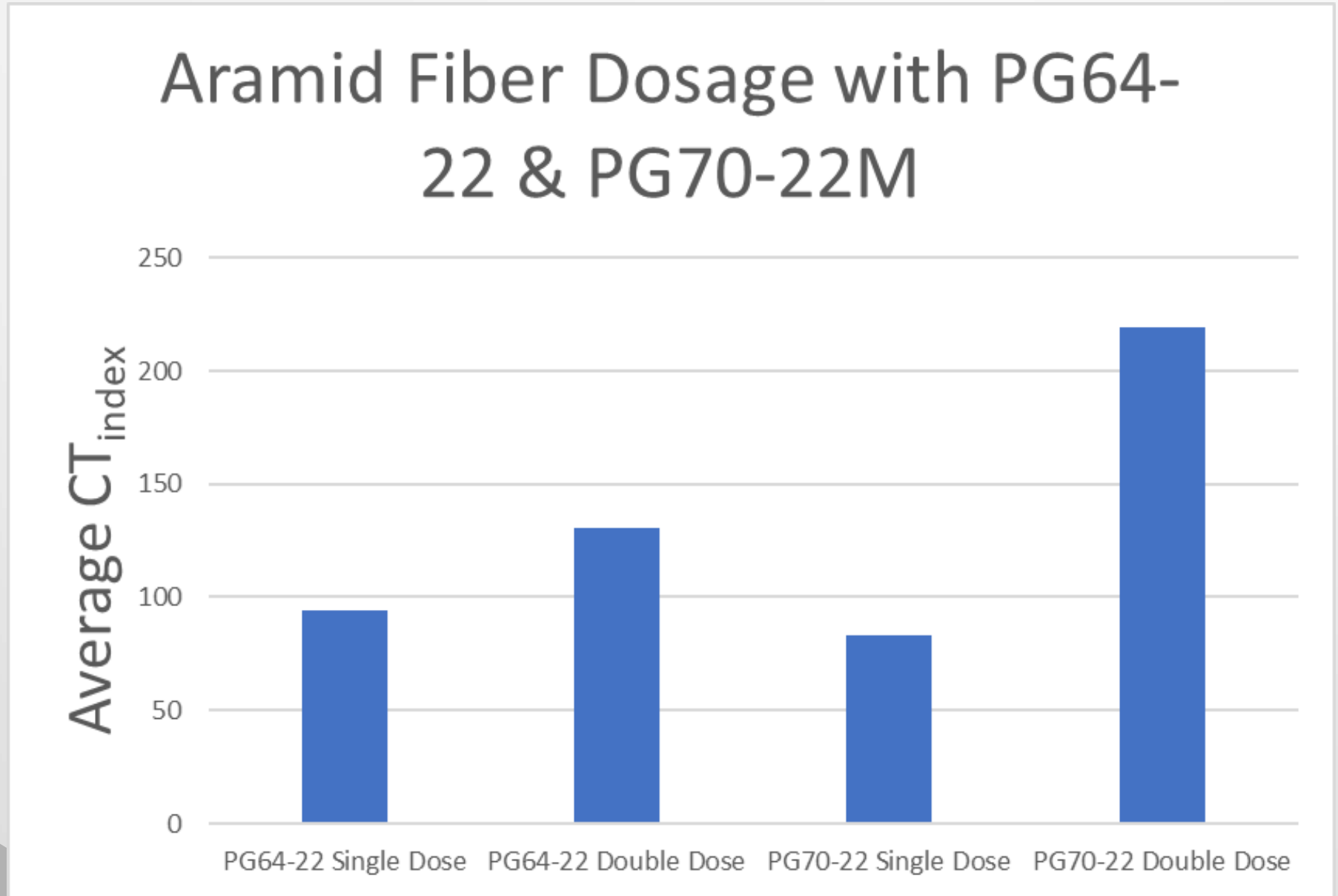
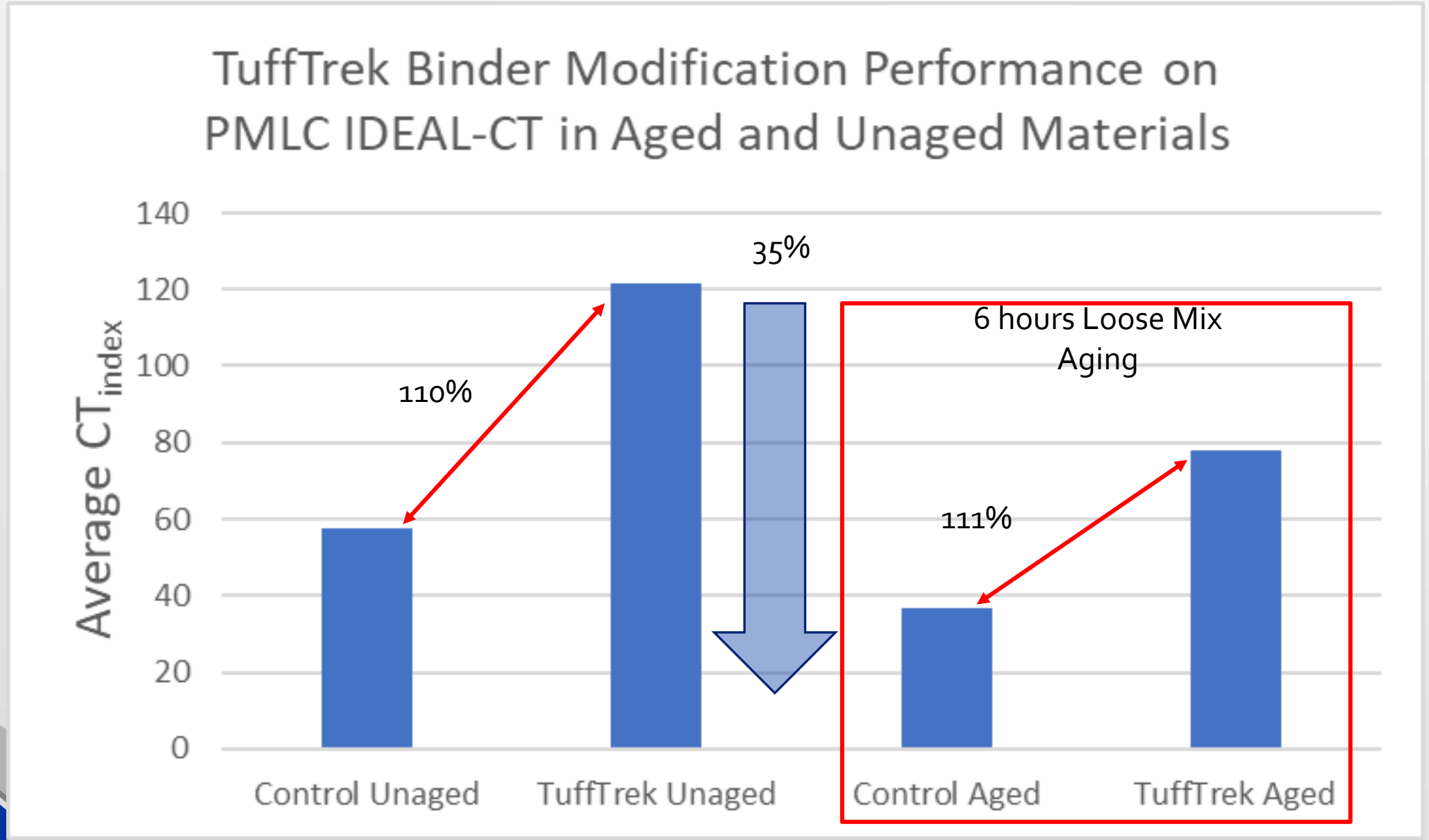
Other Modifiers in IDEAL-CT

Mixture Modifier – Aramid Fiber



Binder Modifier – Bio Oil



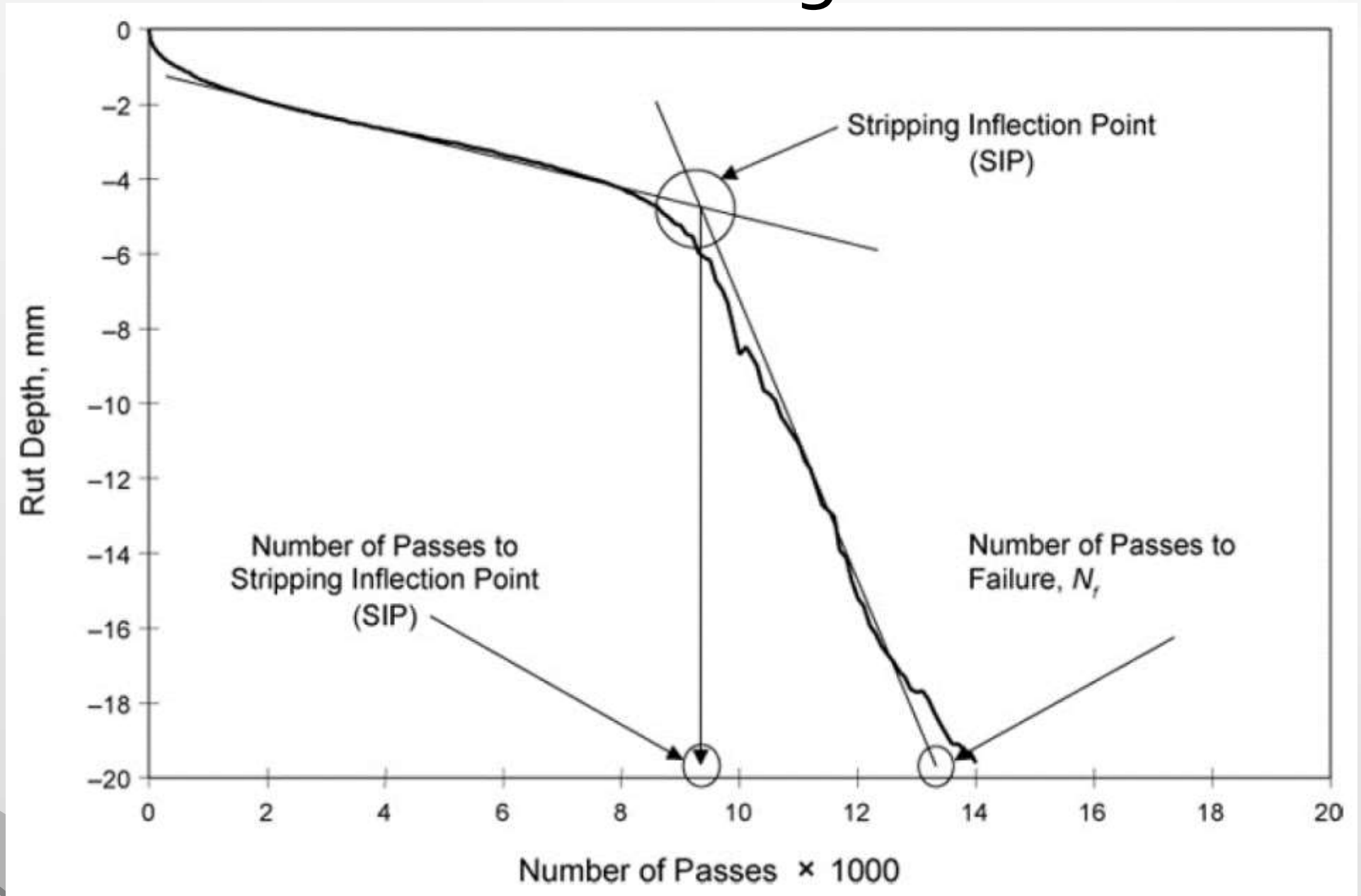
HWT
Test Overview

Balanced Mix Design

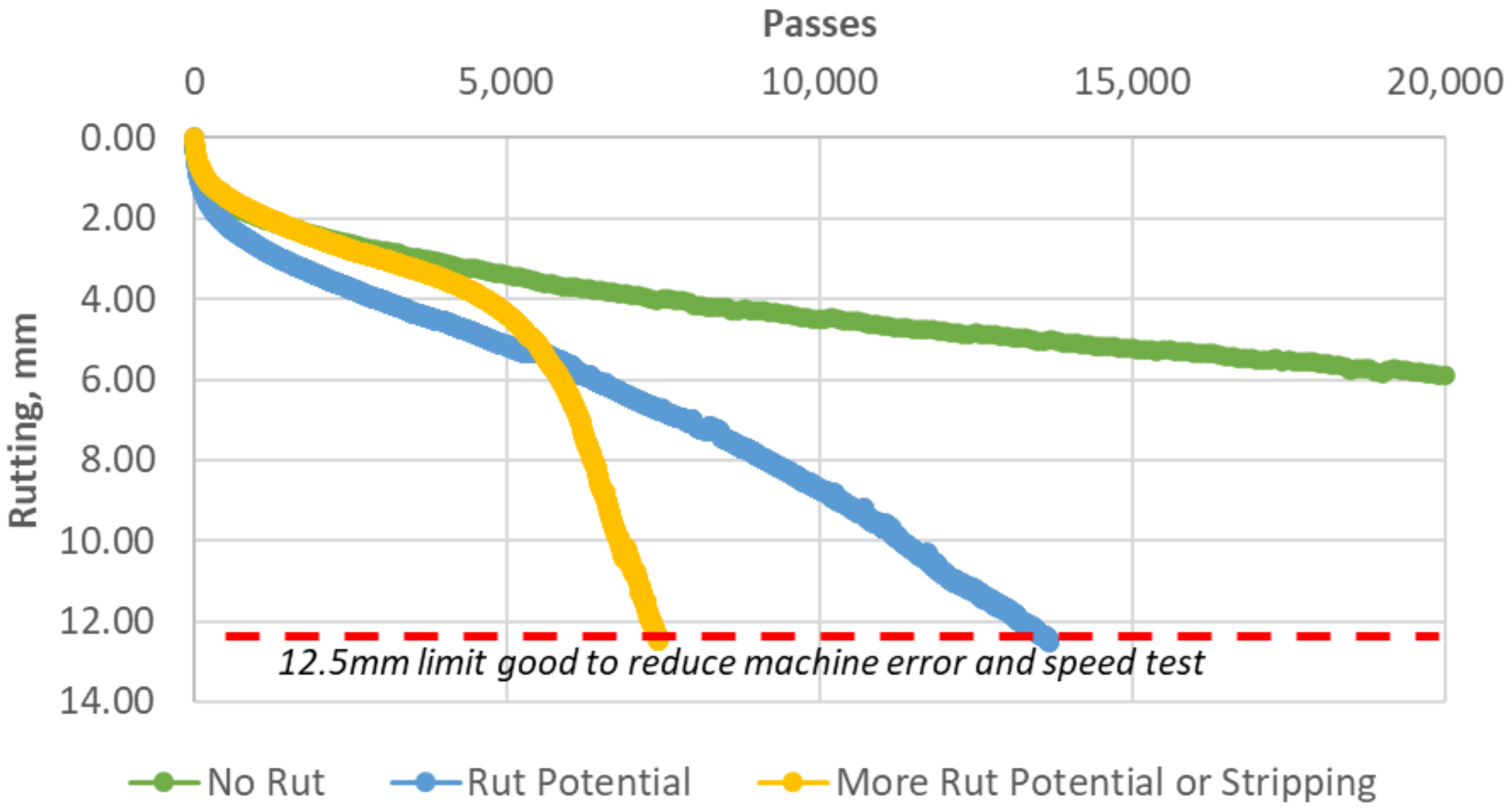
Hamburg Wheel Tracker (AASHTO T324)

- Accelerated rut depth test
- Simulates rut susceptibility by running a loaded wheel over a set
  of asphalt samples repeatedly
- Correlated to field performance
  to make predictions on rutting and moisture susceptibility

HWT Rutting Curve



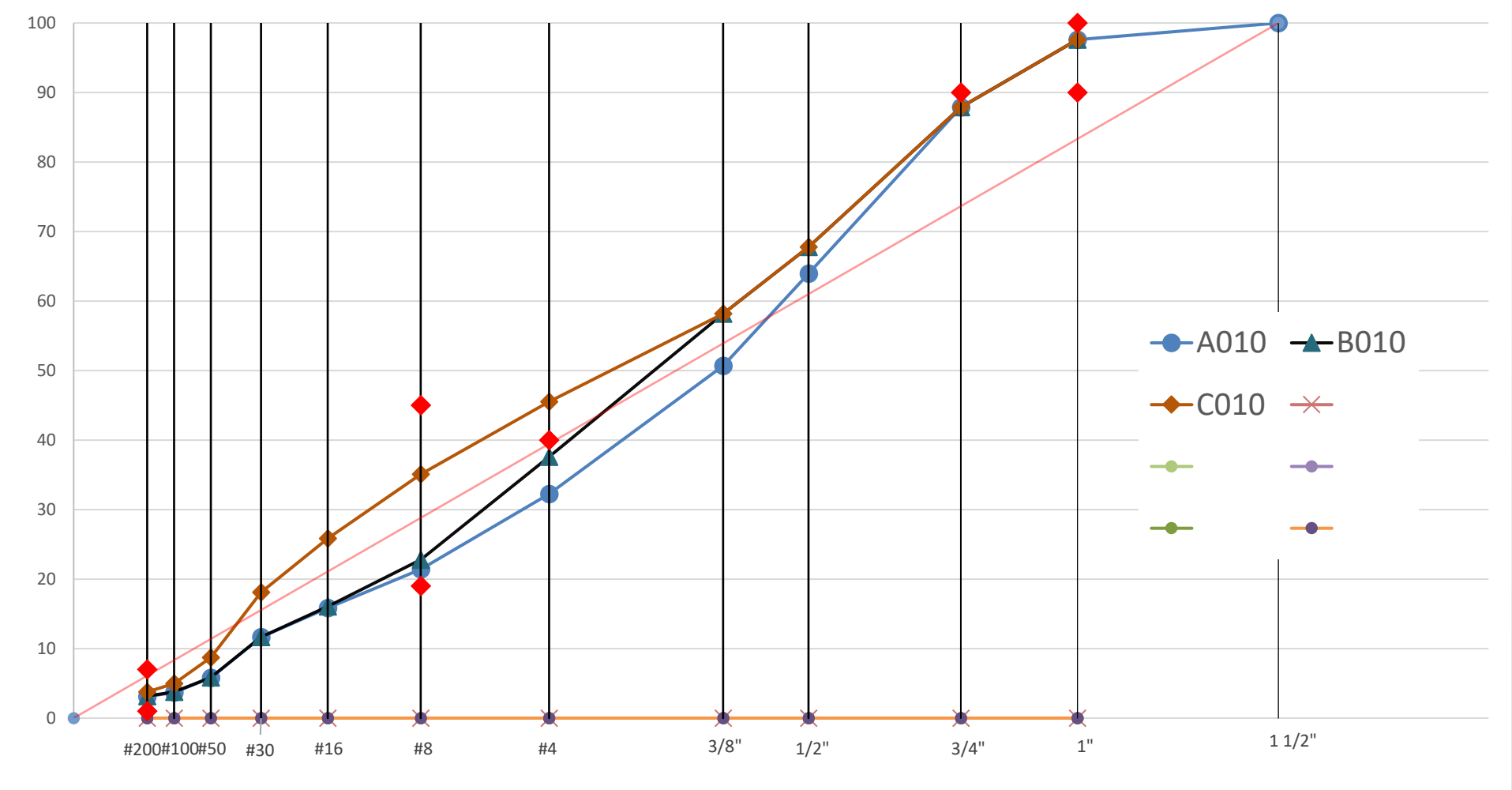
Example Hamburg Wheel Tracker Data Trace



Mix Design Examples

Balanced Mix Design

Building Gradation

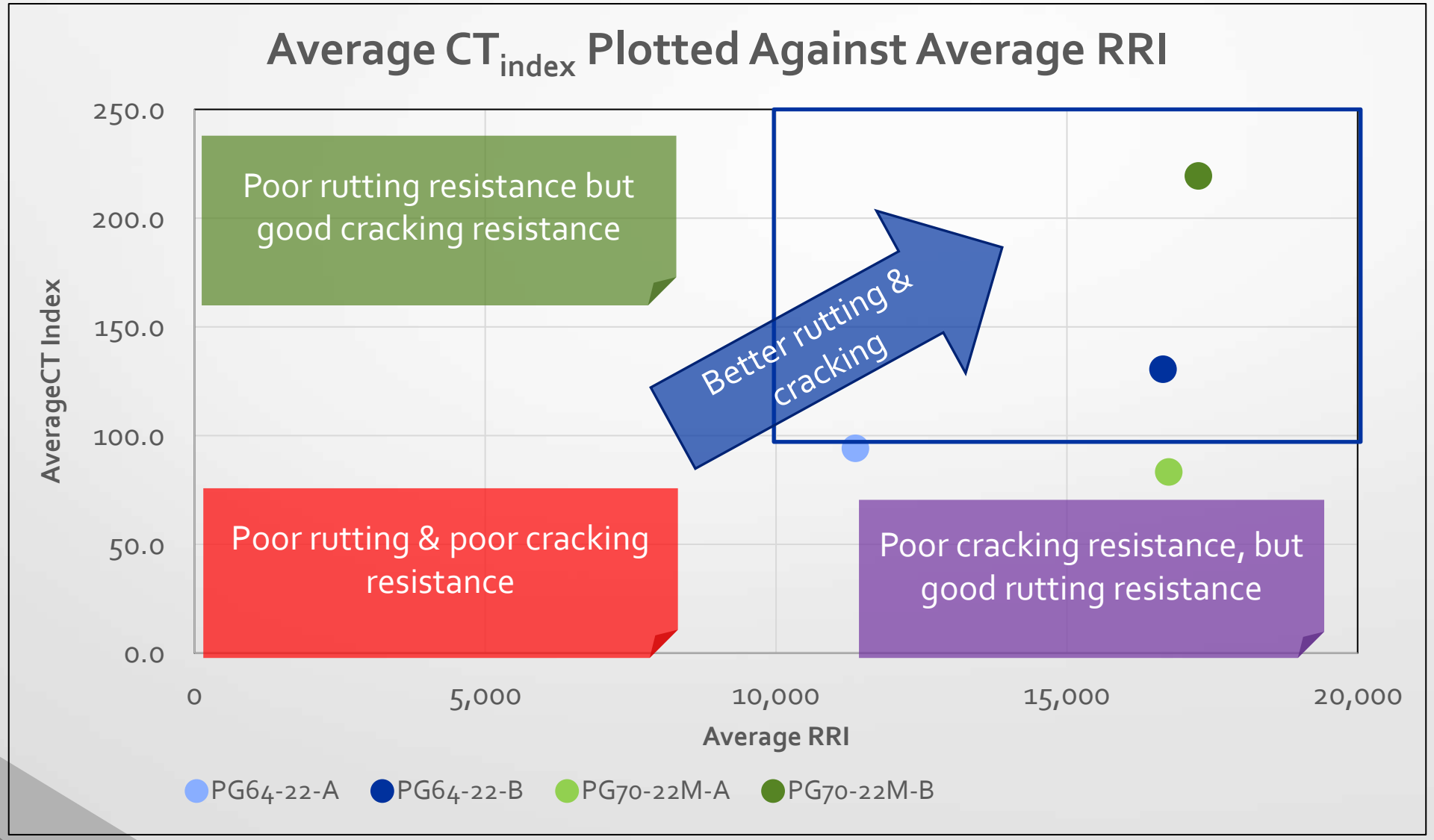


Trial Blends

Volumetric Mixture Data				
	Mix ID	A010	B010	C010
Mix	% AC	4.5	4.5	4.5
	G_{mm}	2.480	2.480	2.480
	G_{se}	2.659	2.659	2.659
N_{Design}	G_{mb} @ N_{des}	2.284	2.273	2.371
	Density @ N_{des}	92.1	91.7	95.6
	Voids @ N_{des}	7.9	8.3	4.4
	VMA	16.8	17.2	13.6
	VFA	53.0	51.7	67.6
	P_{ba}	0.6	0.6	0.6
	P_{be}	3.9	3.9	3.9
	V_{be}	8.9	8.9	9.2
	Delta P_b	-0.40	-0.37	-0.48
	% #200	3.1	3.2	3.8
	DP	0.8	0.8	1.0

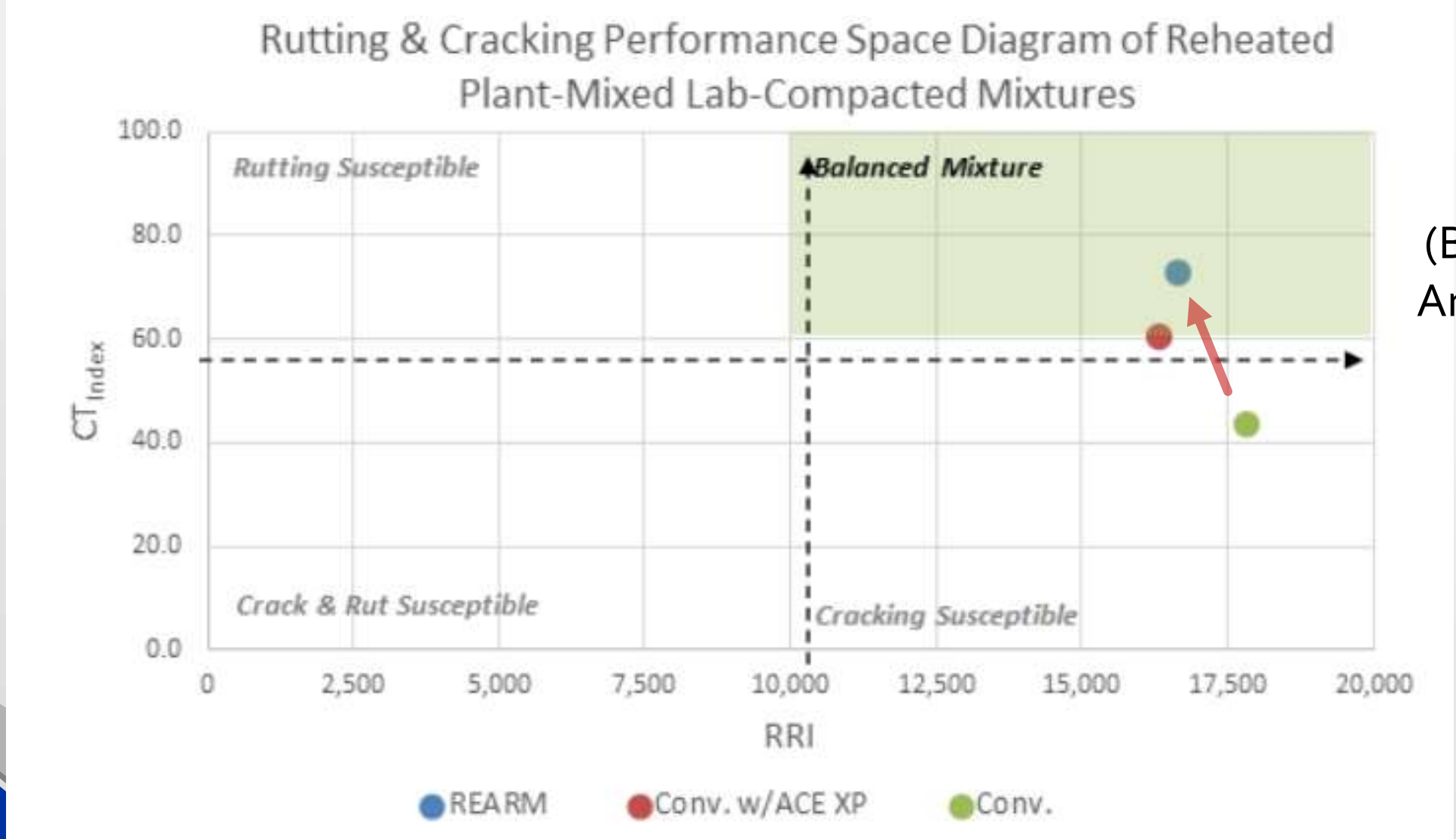
The "Balancing" Act

Test limits vary state to state and on traffic load



BMD High RAP Example: Louisville, KY

36% RAP Project



Soybean (Bio) Oil and Aramid Fiber

Best Practices for BMD

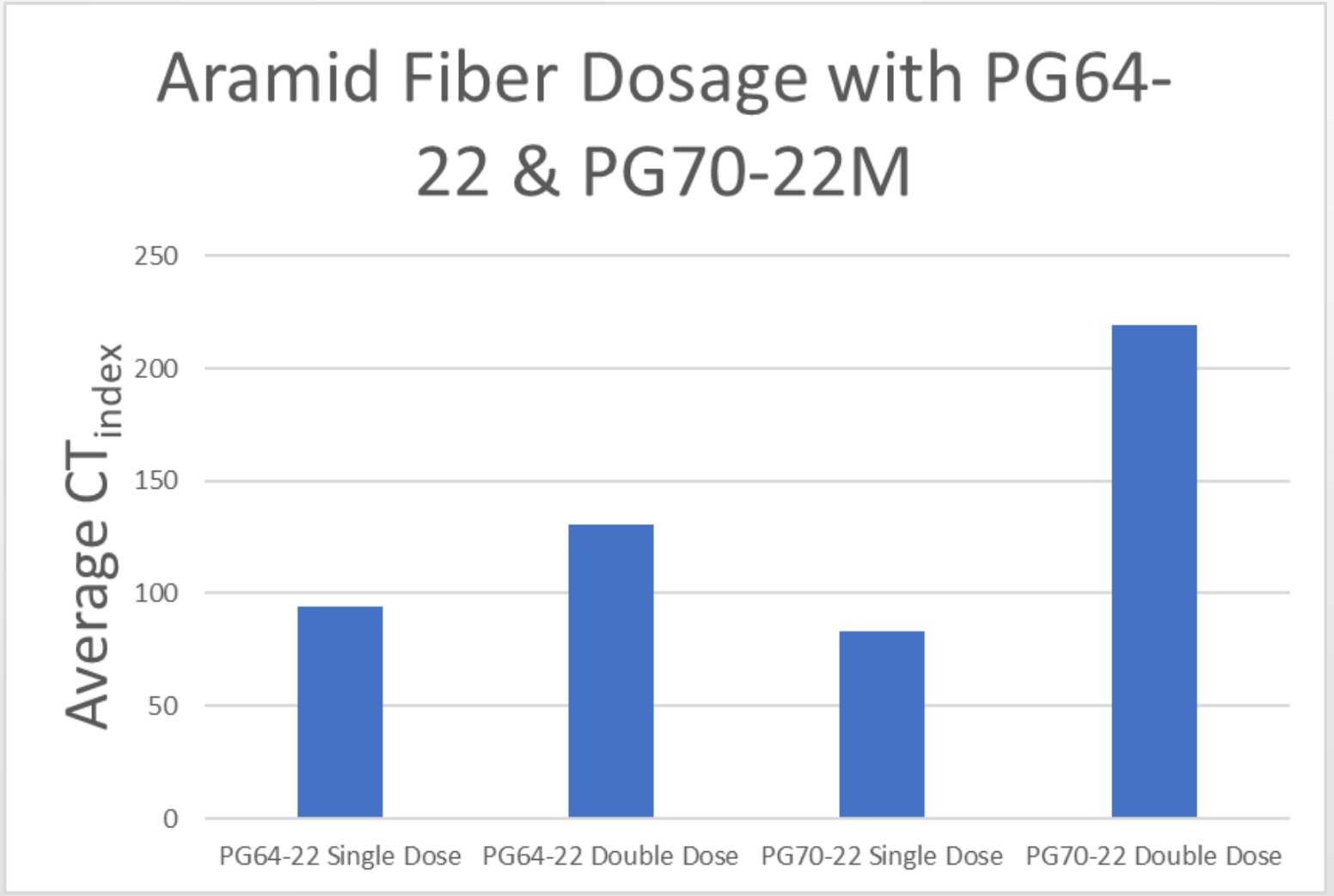
- **Open mix** (middle size agg) to allow room for asphalt
  - More VMA is usually a good indicator
  - Can improve rutting and cracking
  - Stay on min to left side of VFA curve to avoid rutting (overfilling) issue
- **Time in oven/silo** can worsen cracking (CT) and improve HWT. Heat ages binder, increase absorption, and releases RAP binder.
- Use **best lab practices** (batching, consistency) for more uniform test results

Best Practices for BMD (cont.)

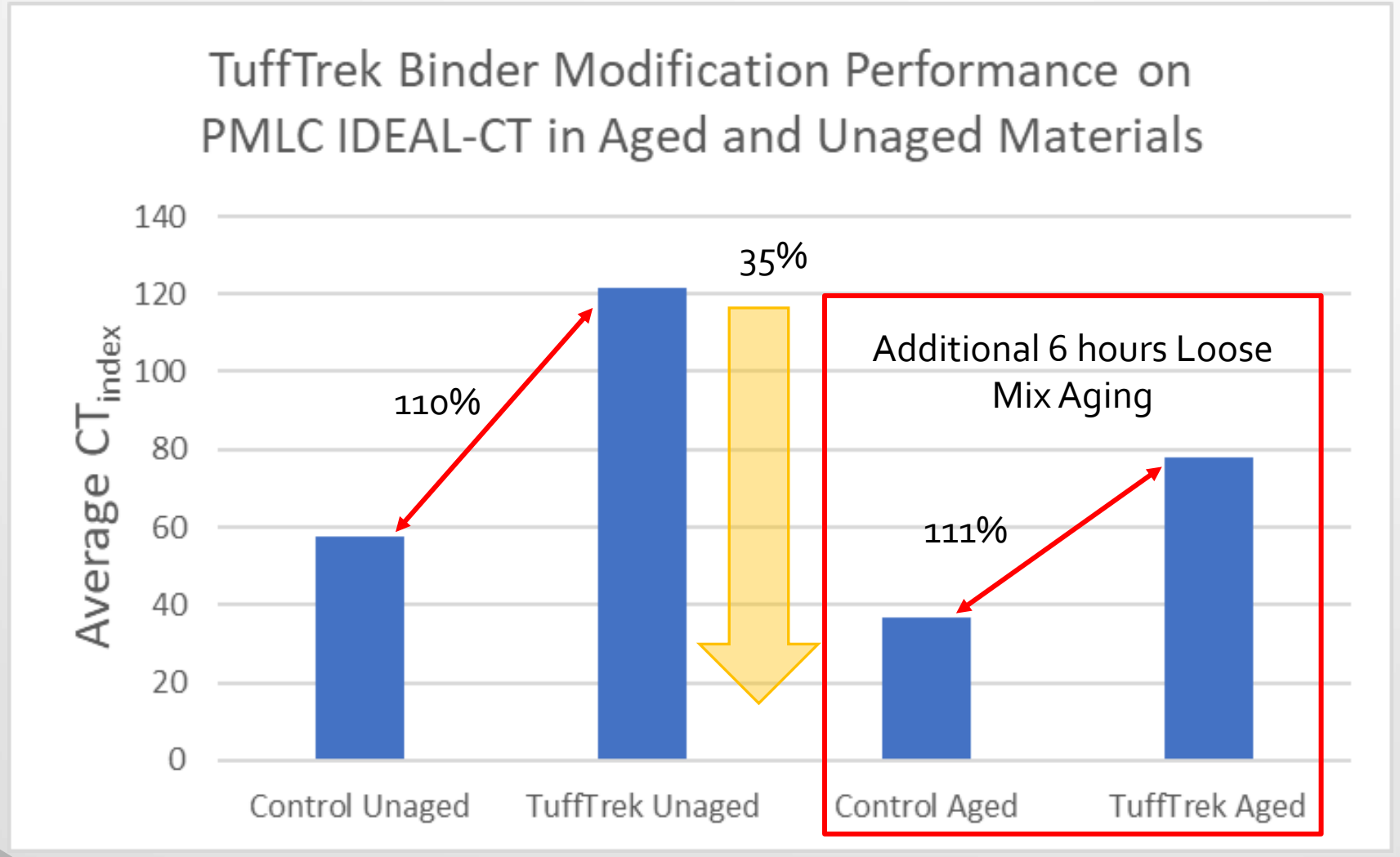
- **Grade (test) RAP** by heating and making IDEAL-CT samples. Can add 1-2% asphalt binder but be consistent.
- **Agg can make a difference** in HWT and IDEAL-CT. Granite best, then limestone, and quartz.
- Try **various binder sources and modifiers** (bio oil, aramid fiber, liquid modifiers, etc.)

Mix Modification

Mixture Modifiers

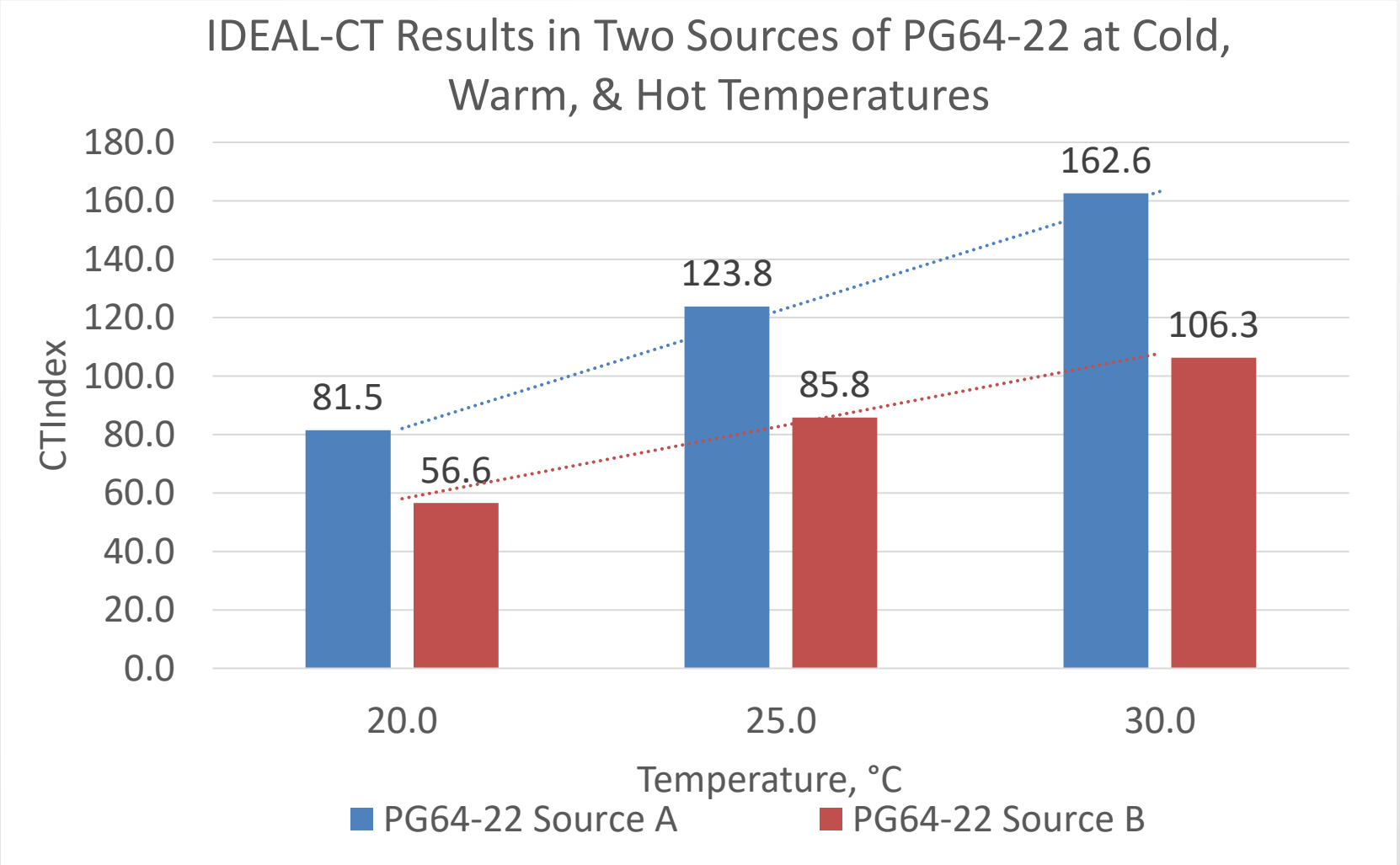


Mixture Modifiers

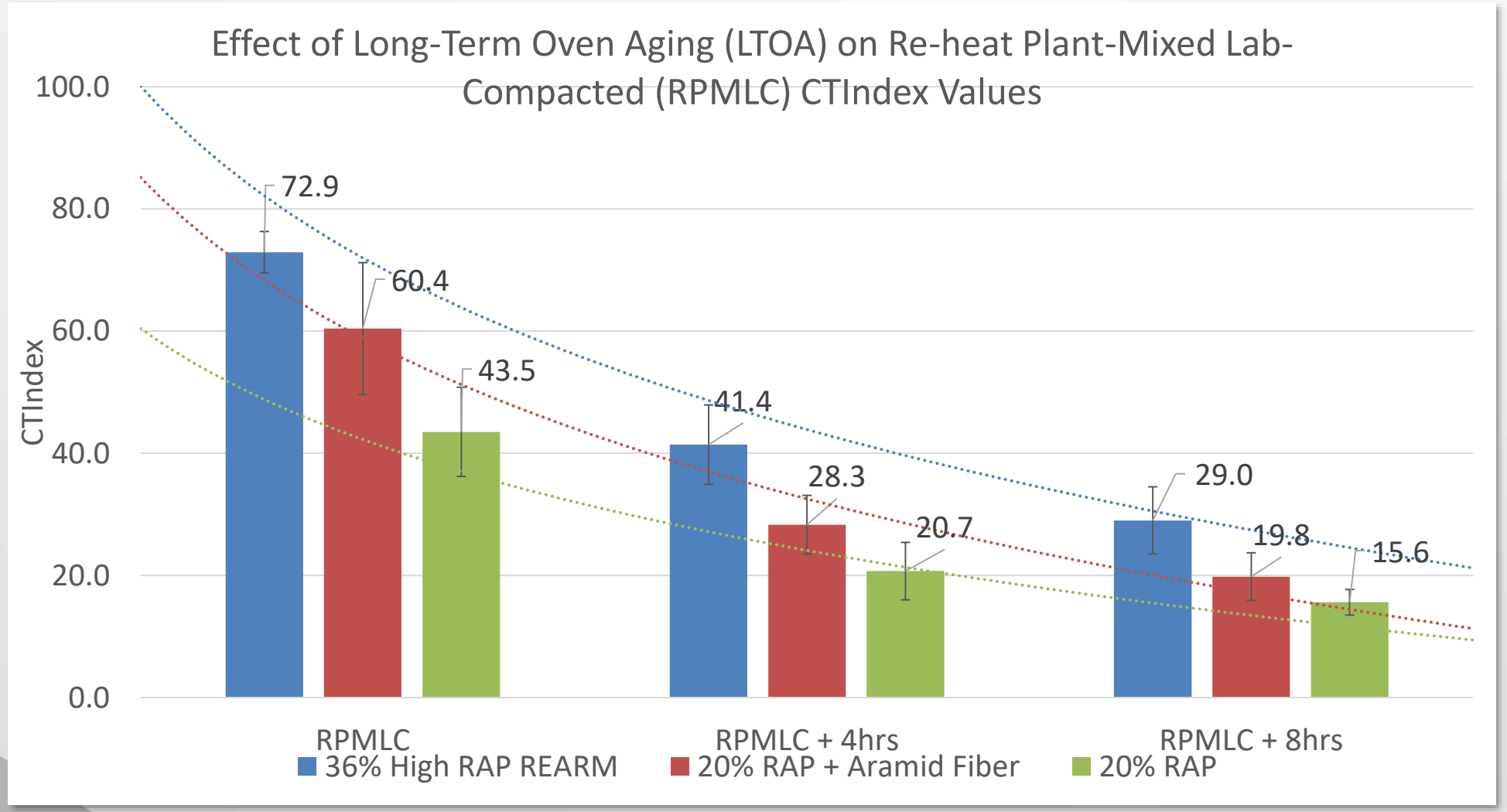


PG64-22 CT Results

- Virgin 9.5mm (0.38D) Central KY Limestone Design
- 5.4% AC



High RAP Mixture & Aging

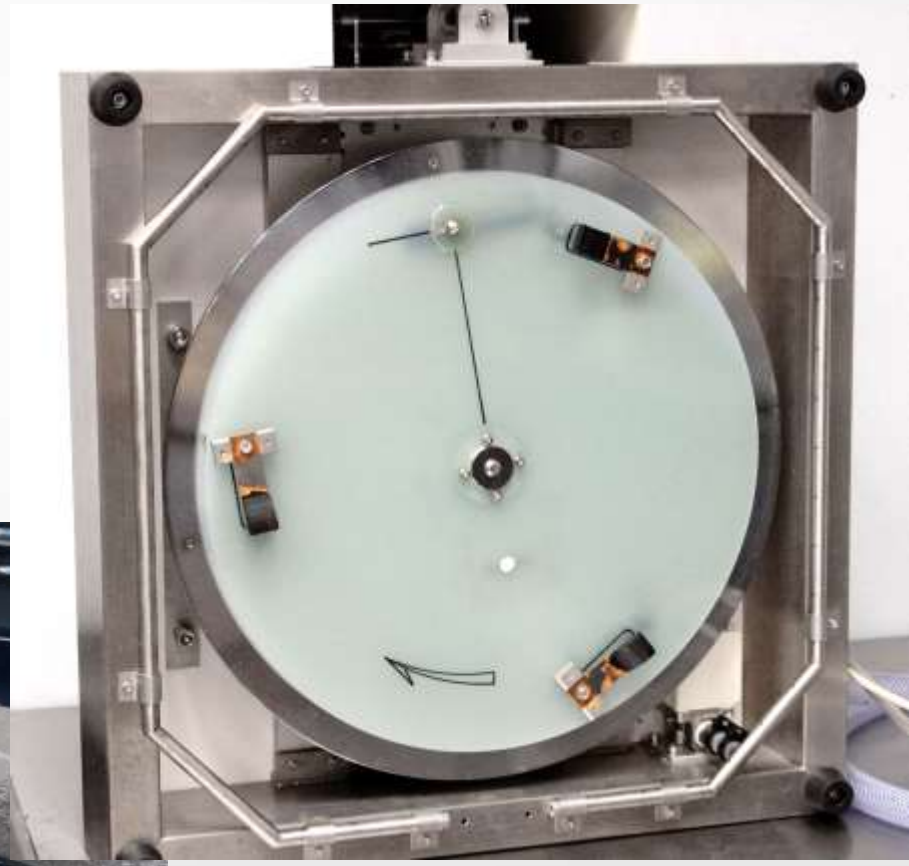


Factors on IDEAL-CT, HWT/APA, & Density

Factor	IDEAL-CT	HWT	Density
Increase %AC (assuming typical PG)	+++	---	+++
Lower PG	++	--	+
Higher PG	--	++	-
Time Under Heat (oven or silo)	---	+++	-
Increase RAP (generally stiffens)	--	++	-
Increase DP (dust-asphalt ratio)	--	++	?
High absorption agg	--	++	--
Recycling Agents – bio oil type (soybean or corn oil)	++	--	+
Warm Mix Asphalt (WMA) Additive	+	- ?	++
Aramid fibers (polymer fiber)	++	++	?
Thicker paving mat	NA	NA	+++

Agg Polishing & Dynamic Friction Testing (DFT)

Agg Polishing & Dynamic Friction Testing (DFT)



Performance/Index Testing Does Not Have to Be Complicated to Be Useful!

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