NATIONAL ACADEMIES
Sciences Engineering Medicine

TRB TRANSPORTATION RESEARCH BOARD

TRB Webinar: Ruggedness Testing—Evaluating Asphalt Mixture Cracking Resistance

December 5, 2022

12:00 – 1:30 PM

PDH Certification Information

1.5 Professional Development Hours (PDH) – see follow-up email

You must attend the entire webinar.

Questions? Contact Andie Pitchford at TRBwebinar@nas.edu

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Providers Program. Credit earned on completion of this program will be reported to RCEP. A certificate of completion will be issued to participants that have registered and attended the entire session. As such, it does not include content that may be deemed or construed to be an approval or endorsement by RCEP.

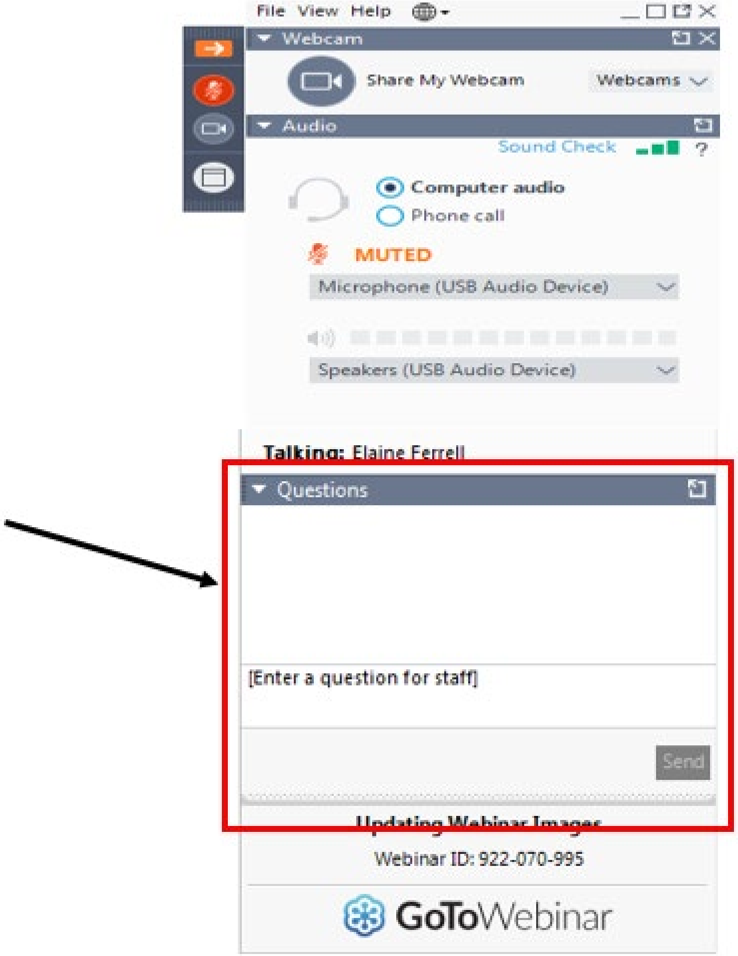
RCEP
REGISTERED CONTINUING EDUCATION PROGRAM

Learning Objectives

- Make informed decisions about implementing new research to ruggedness testing of cracking tests

Questions and Answers

- Please type your questions into your webinar control panel
- We will read your questions out loud, and answer as many as time allows



Today's presenters

Tom Bennert
bennert@soe.rutgers.edu
Rutgers University

Fujie Zhou
f-zhou@tti.tamu.edu
Texas A&M Transportation Institute

Casey Nash
Casey.B.Nash@maine.gov
Maine Department of Transportation

Ruggedness of Laboratory Tests for Asphalt Mixture Cracking Resistance

Texas A&M Transportation Institute

Fujie Zhou

December 5, 2022

Acknowledgment and disclaimer

- This investigation is being sponsored by TRB under the NCHRP Program 09-57A. Data reported are a work in progress. Contents of this research may have not been reviewed by the project panel of NCHRP, nor do they constitute a standard, specification, or regulation. The contents of this presentation reflect the views of the authors who are solely responsible for the facts and accuracy of the data presented herein and do not necessarily reflect the official views or policies of any agency or institute. Trade names were used solely for information purposes and not for product endorsement, advertisement, promotions, or certification.

Presentation Outline

- Introduction
  - Motivation, background, and objective
- Overview of ruggedness testing
- NCHRP 9-57A ruggedness testing
  - Ruggedness test preparation, execution, analysis, and standard modification
- Summary

Introduction: motivation

- DOTs and asphalt industry need reliable and simple cracking tests
  - Mix design,
  - Production QA (including QC at asphalt plant), and
  - Pavement ME design

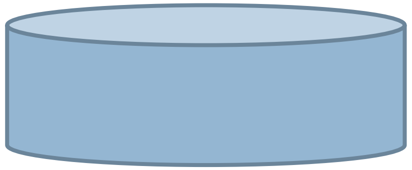
   

Introduction: background

- NCHRP 9-57's original work
  - Identify cracking tests by literature review and national workshop in 2015
  - Develop <u>three</u> experimental designs for
    - *Ruggedness test to fine tune crack test procedures*
    - Field validation of cracking tests with 49 sections (9 MnROAD2008 and 40 LTPP)
    - Round robin testing to develop a precision statement for each cracking test
- https://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP09-57_FR.pdf

Introduction: objective

- Objective of NCHRP 9-57A ruggedness testing
  - Identify significant influence factors of each specific cracking test, and then
  - Establish limits (or tolerances) for controls.
  - For example:
    - Specimen thickness, i.e. ±2 mm or ±1 mm
    - Test temperature: ±0.5°C or ±1.0°C
    - Air voids: ±0.5% or ±1.0%



Ruggedness testing overview

- NCHRP 9-57A follows ASTM E1169, *Standard Practice for Conducting Ruggedness Tests*; *one laboratory and six steps*:
  - 1) Select testing factors and their levels: *7 factors selected for each test*
  - 2) Select test materials: *3 representative asphalt mixes*
  - 3) Develop experimental design: *Replicated 8-run Plackett Berman (PB) design*
  - 4) Execute the experimental design: *Random run order*
  - 5) Perform statistical analysis: *Student's t-test*
  - 6) Revise test methods as needed

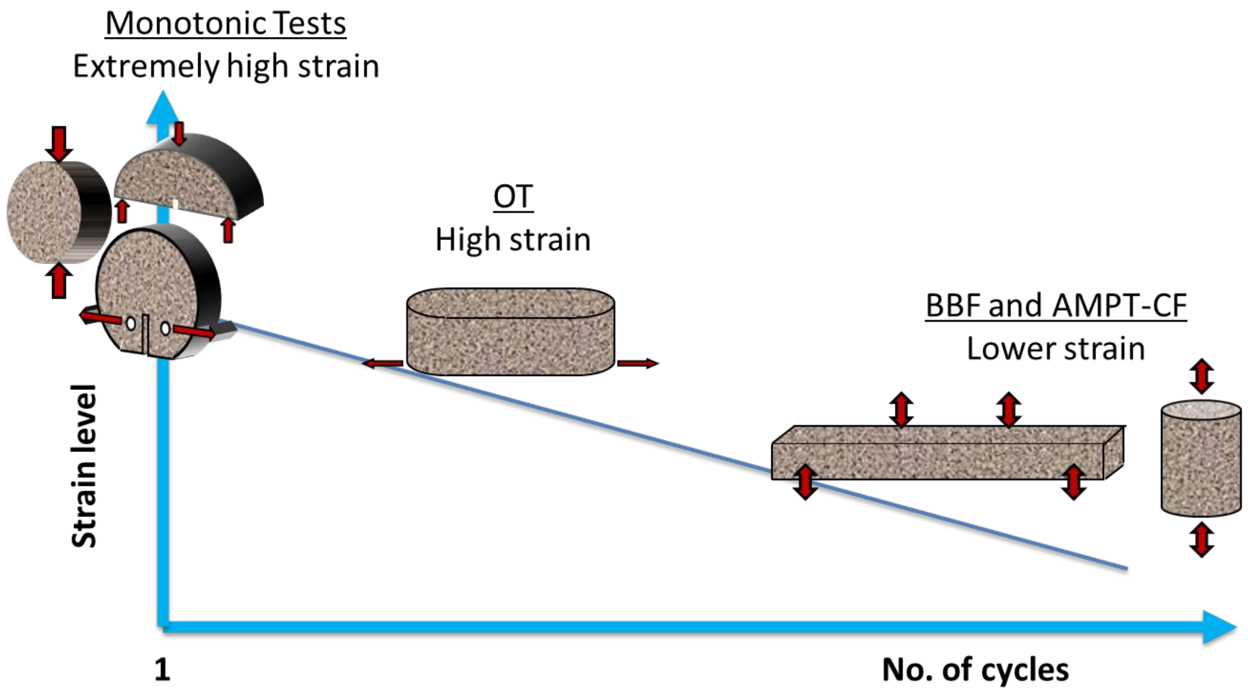
Ruggedness test preparation: select 8 cracking tests

- Ten cracking tests: 1-8 selected for NCHRP 9-57A; FHWA working on 9-10

Crack Test Standard	Index para.	Performance para.
1. ASTM D7013: Disk-shaped compact tension test (DCT)	Gf	
2. AASHTO TP105: Semi-circular bend at low temp. (SCB-LT)	Gf	
3. AASHTO TP124: Semi-circular bend for flexibility index (SCB-FI)	FI	
4. ASTM D8044: SCB for critical strain energy release rate (SCB-Jc)	Jc	
5. ASTM D8225: Indirect tensile cracking test (IDEAL-CT)	CT_{index}	
6. Tex-248-F: Overlay test (OT)	N, CFE, CRI	A and n
7. AASHTO T321: Bend beam fatigue test (BBF)	N	k_1, k_2, and k_3
8. University of Florida: Indirect tension test (UF-IDT)	ER	
9/10. AASHTO TP107/TP133: AMPT-cyclic fatigue test (AMPT-CF)	Sapp	C-S curve

Ruggedness test preparation: select 8 cracking tests

- Ten cracking tests: monotonic vs. cyclic vs. both
  - **4** monotonic tests (DCT, SCB-FI, SCB-Jc, and IDEAL-CT); **4** cyclic tests (OT, BBF, AMPT cyclic fatigue (AMPT-CF)) and **2** cyclic/monotonic tests (UF-IDT and SCB-LT)



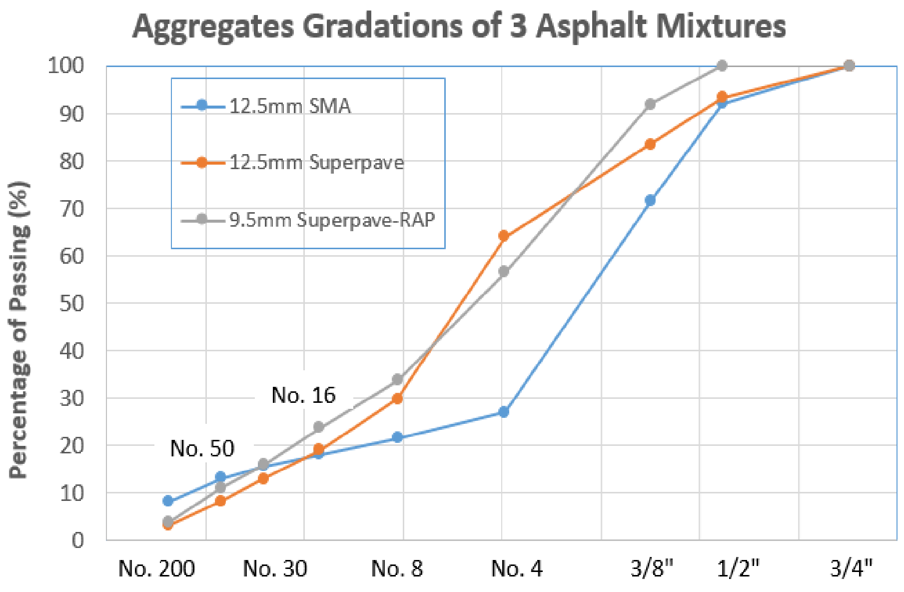
Ruggedness test preparation: select factors and levels

- Seven factors were selected for each cracking test, such as DCT below

No.	Factor	Standard Value	High Level	Low Level
1	Specimen thickness	50 mm	55 mm (Std.+5 mm)	45 mm (Std.–5 mm)
2	Notch depth	62 mm	65 mm (Std.+3 mm)	59 mm (Std.–3 mm)
3	Loading hole location	25 mm from the notch	28 mm (Std.+3 mm)	22 mm (Std.–3 mm)
4	Air voids	7.0%	8.0% (Std.+1%)	6.0% (Std.–1%)
5	Crack opening rate	1 mm/min	1.05 mm/min (Std.+5%)	0.95 mm/min (Std.–5%)
6	Test temperature	PG low+10°C	PG low+11°C (Std.+1°C)	PG low+9°C (Std.+1°C)
7	Specimen conditioning time	8–16 hr	8 hr	2 hr

Ruggedness test preparation: select materials

- Three representative mixes were approved by the panel.
  - 12.5 mm SMA with PG76-22, 6.3%AC
  - 12.5 mm Superpave with PG64-22, 5.4%AC
  - 9.5 mm Superpave with PG58-28 and 20% RAP binder replacement, 5.1%AC



Ruggedness test preparation: experimental design

- ASTM E1169: Replicated 8-run PB design

PB Design Order	Actual Run Order	Testing Factors							Test Result	
		A	B	C	D	E	F	G	Replicate1	Replicate2
1		1	1	1	-1	1	-1	-1		
2		-1	1	1	1	-1	1	-1		
3		-1	-1	1	1	1	-1	1		
4		1	-1	-1	1	1	1	-1		
5		-1	1	-1	-1	1	1	1		
6		1	-1	1	-1	-1	1	1		
7		1	1	-1	1	-1	-1	1		
8		-1	-1	-1	-1	-1	-1	-1		
Ave +										
Ave −										
Main effect										

Ruggedness test execution: specimen preparation

- No. of specimens prepared for each cracking test

Test Method	No. of Factors	No. of Material	No. of Runs	No. of Replicate	Safety Factor	No. of Specimen
DCT	7	3	8	2	1.5	72
SCB-LT	7	3	8	2	1.5	72
SCB-FI	7	3	8	2	1.5	72
SCB-Jc	7	1	8	2	1.5	288
IDEAL-CT	7	3	8	2	1.5	72
OT	7	3	8	2	1.5	72
BBF	7	3	8	2	1.5	72
UF-IDT	7	3	8	2	1.5	72

Ruggedness test execution: random runs

- DCT run in random order

PB Design Order	Actual Run Order	Specimen Thickness, mm	Notch Depth, mm	Loading Hole Location, mm	Air Voids, %	Crack Opening Rate, mm/min	Test Temperature, °C	Specimen Conditioning Time, hr
1	6	55	65	28	6.0	1.05	PG low+9	2
2	15	45	65	28	8.0	0.95	PG low+11	2
3	13	45	59	28	8.0	1.05	PG low+9	8
4	16	55	59	22	8.0	1.05	PG low+11	2
5	8	45	65	22	6.0	1.05	PG low+11	8
6	3	55	59	28	6.0	0.95	PG low+11	8
7	4	55	65	22	8.0	0.95	PG low+9	8
8	12	45	59	22	6.0	0.95	PG low+9	2
9	7	55	65	28	6.0	1.05	PG low+9	2
10	11	45	65	28	8.0	0.95	PG low+11	2
11	2	45	59	28	8.0	1.05	PG low+9	8
12	14	55	59	22	8.0	1.05	PG low+11	2
13	10	45	65	22	6.0	1.05	PG low+11	8
14	1	55	59	28	6.0	0.95	PG low+11	8
15	5	55	65	22	8.0	0.95	PG low+9	8
16	9	45	59	22	6.0	0.95	PG low+9	2

Ruggedness test execution: test results

- DCT test results: *12.5 mm Superpave mixture*

PB Order	A: Specimen Thickness	B: Notch Depth	C: Loading Hole Location	D: Air Voids	E: Crack Opening Rate	F: Test Temperature	G: Specimen Conditioning Time	Rep 1 G_f	Rep 2 G_f	Rep Ave G_f	Rep G_f Diff.
1	1	1	1	-1	1	-1	-1	552	420	486	-132
2	-1	1	1	1	-1	1	-1	332	297	315	-35
3	-1	-1	1	1	1	-1	1	301	319	310	18
4	1	-1	-1	1	1	1	-1	507	529	518	22
5	-1	1	-1	-1	1	1	1	322	482	402	160
6	1	-1	1	-1	-1	1	1	332	457	395	125
7	1	1	-1	1	-1	-1	1	374	443	409	69
8	-1	-1	-1	-1	-1	-1	-1	303	383	343	80
Ave +	451.75	402.75	376.25	387.75	429.00	407.25	378.75			S_d	92.63
Ave −	342.38	391.38	417.88	406.38	365.13	386.88	415.38			S_r	65.50
Main Effect	109.38	11.38	-41.63	-18.63	63.88	20.38	-36.63			S_{effect}	32.75

Ruggedness test: data analysis

- Student's *t* test analysis: *DCT of 12.5 mm Superpave mixture*
  - *Specimen thickness is statistically significant factor. Estimated tolerance for specimen thickness is* ±3.5 mm

Effect Order	Factor	|Effect|	Student's *t*	*p*-value	Half-Normal
7	A (Specimen thickness)	109.38	3.34	0.012	1.803
1	B (Notch depth)	11.38	0.35	0.739	0.09
5	C (Loading hole location)	41.63	1.27	0.244	0.921
2	D (Air voids)	18.63	0.57	0.587	0.272
6	E (Crack opening rate)	63.88	1.95	0.092	1.242
3	F (Test temperature)	20.38	0.62	0.554	0.464
4	G (Specimen conditioning time)	36.63	1.12	0.300	0.674

Ruggedness test: test procedure revision

- ASTM D7313 DCT

Factor	Tolerance used in NCHRP 9-57A	Current Spec D7313-13	Recommended Tolerance Adopted in new ASTM D7313-20
A (Specimen thickness), mm	±5	±5	±3.5
B (Notch depth), mm	±3	±2.5	±2.5
C (Location of loading hole), mm	±3	±2.5	±2.5
D (Air voids), %	±1.0	None	a note added under subsection 6.2.1
E (Crack opening rate), mm/min	±0.05	±0.02	±0.05
F (Test temperature), °C	±1.0	±0.2	±0.5
G (Specimen conditioning time), hr	2-8	8-16	2-8

Ruggedness test: test procedure revision

- AASHTO TP105-13: SCB at low temperature

Factor	Tolerance Used in NCHRP 9-57A	Current Requirement in AASHTO TP 105-13	Recommended Tolerance
A (Specimen thickness), mm	±2	±2	±2.0
B (Notch depth), mm	±2	±1.0 in Figure 3 ±0.5 under 10.2	±2.0
C (Notch location)	Center or 2 mm off	±0.0 (symmetry of each half)	The maximum allowable offset between the notch center and the axis of symmetry of the specimen is 2 mm
D (Specimen height), mm	±2	±0.0 (identical halves)	The height of the semicircular specimen is 73.5 ± 2 mm
E (Air voids), %	±1.0	None	± 1.0
F (Crack opening rate), mm/min	±0.05	±0.0	±0.05
G (Test temperature), °C	±1.0	±0.5	±0.5

Ruggedness test: test procedure revision

- AASHTO TP124-18: SCB-FI

Factor	Tolerance Used in NCHRP 9-57A	Current Requirement in AASHTO TP 124-18	Recommended Tolerance
A: Specimen thickness (mm)	±2	±1	±1
B: Notch depth (mm)	±2	±1	±2
C: Notch location (mm)	±2	Cut notch along the axis of symmetry of semicircular specimen	The maximum allowable offset between the notch center and the axis of symmetry of the specimen is 2 mm
D: Specimen height (mm)	±2	Cut each cylindrical specimen exactly in half	The height of the semicircular specimen is 73.5 ± 2 mm
E: Air voids (%)	±1.0	±1.0	±0.5
F: Loading rate (mm/min)	±2	±1	±1
G: Test temperature (°C)	±1.0	±0.5	±0.5

Ruggedness test: test procedure revision

- ASTM D8044-16: SCB-Jc

Factor	Tolerance Used in NCHRP 9-57A	Current Requirement in ASTM D8044-16	Recommended Tolerance
A (Specimen thickness), mm	±2	±1.0	±2.0
B (Notch depth), mm	±2	±1.0	±2.0
C (Notch location)	Center or 2 mm off	The notch shall be in the center of the specimen within 0.3 mm	The maximum allowable offset between the notch center and the axis of symmetry of the specimen is 2 mm
D (Specimen height), mm	±2	Cut along its central axis into two equal semicircular samples. The height (radius) of the two samples shall be within 1 mm of each other.	The height of the semicircular specimen is 73.5 ± 2 mm
E (Air voids), %	±1.0	±0.5	±1.0
F (Loading rate), mm/min	±0.02	Not defined	±0.02
G (Test temperature), °C	±1.0	±0.3	±0.5

Ruggedness test: test procedure revision

- ASTM D8225-19: IDEAL-CT

Factor	Tolerance Used in NCHRP 9-57A	Current Requirement in ASTM D8225-19	Recommended Tolerance
A: Specimen thickness (mm)	±2	±1	±1
B: Specimen location (mm)	Center or 2 mm offset	Centered in the fixture	2 mm maximum off the center of the loading fixture
C: Air voids (%)	±1.0	±0.5	±0.5
D: Loading rate (mm/min)	±2	±2	±3
E: Contact load (kN)	0.1 or 0	0	0
F: Test temperature (°C)	±1	±1	±1
G: Conditioning method	Air or water	Air or water	Air or water

Ruggedness test: test procedure revision

- Tex-248-F: OT

Factor	Tolerance Used in NCHRP 9-57A	Current Requirement in Tex-248-F (May 2017)	Recommended Tolerance
A: Specimen height (mm)	±2	±0.5	±0.5
B: Specimen width (mm)	±2	±1	±2
C: Air voids (%)	±1.0	±1.0	±0.5
D: Crack opening displacement (mm)	±0.025	None	±0.02
E: Loading period (frequency) (s)	±1.0	None	±1.0
F: Block weight (lb)	5 or 10	5	5 or10
G: Test temperature (°C)	±1.0	±0.5	±0.5

Ruggedness test: test procedure revision

- AASHTO T321-17: BBF

Factor	Tolerance Used in NCHRP 9-57A	Current Requirement in AASHTO T 321-17	Recommended Tolerance
A (Specimen height), mm	±6	±6	±6
B (Specimen width), mm	±6	±6	±6
C (Specimen length), mm	±6	±6	±6
D (Air voids), %	±1.0	None	One sentence is added to Note 2 under Subsection 7.1
E (Loading frequency), Hz	High level: 10 Low level: 5	None	±2; a new Note 7 is added under Subsection 8.6
F (Strain level)	±5%	None	±5%; a new Note 7 is added under Subsection 8.6
G (Test temperature), °C	±1	±0.5	±0.5

Ruggedness test: test procedure revision

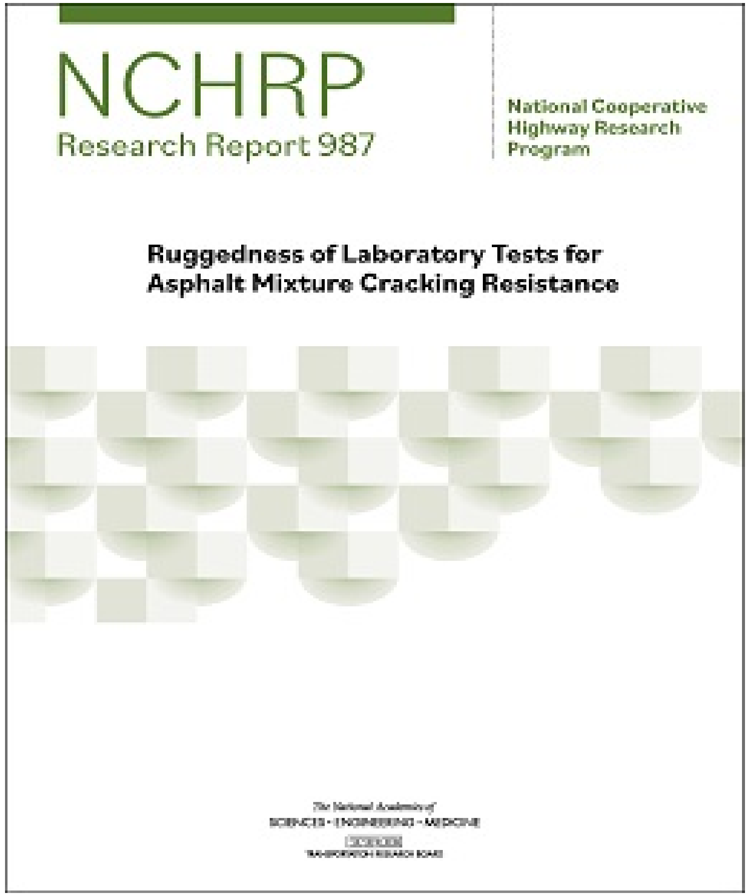
- UF-IDT

Factor	Tolerance Used in NCHRP 9-57A	Current Requirement in UF-IDT Test Method	Recommended Tolerance
A: Specimen thickness (mm)	±2.0	None	±2.0
B: Air voids (%)	±1.0	±0.5	±0.5
C: Rest period between M_R and creep tests (min)	5 or 15	None	A note was added to the test method
D: Temperature equilibrium time (min)	30 or 60	None	30
E: Rest period between creep test and fracture tests (min)	5 or 15	0 or undefined	A note was added to the test method
F: Loading rate (mm/min)	±2.0	None	±2.5
G: Test temperature (°C)	±1.0	±0.5	±0.5

NCHRP 9-57A Research Report 987

- NCHRP Report 987 documents all the work done under Phases I and II.

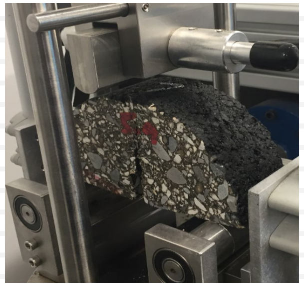
https://nap.nationalacademies.org/catalog/26528/ruggedness-of-laboratory-tests-for-asphalt-mixture-cracking-resistance



Summary

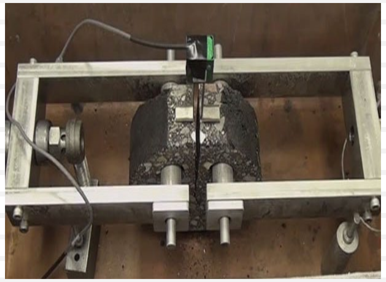
- Ruggedness of eight cracking tests was systematically evaluated under NCHRP 9-57A, following ASTM E1169.
- Three representative asphalt mixtures: 12.5 mm SMA, 12.5 MM Superpave, and 9.5 mm Superpave, were employed in this study
- Revisions were recommended to each test standard. Some recommended revisions have been adopted in the new test standards.

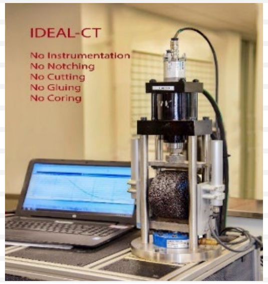
Thank You All!


SCB-FI


SCB-LT

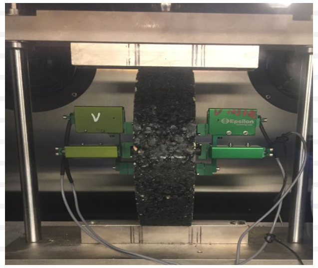

SCB-Jc

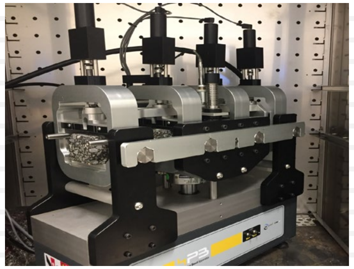

DCT

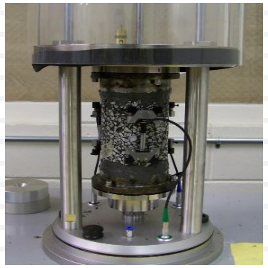


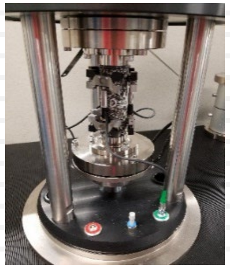
IDEAL-CT

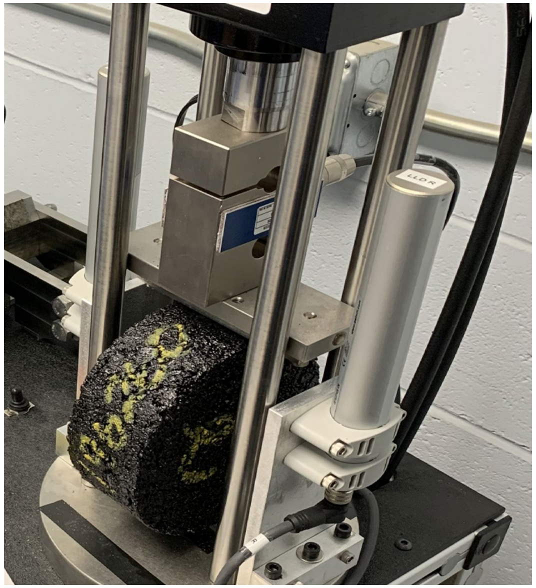

OT


UF-IDT


BBF


AMPT-CF LS


AMPT-CF SS



Asphalt Mixture Cracking Resistance

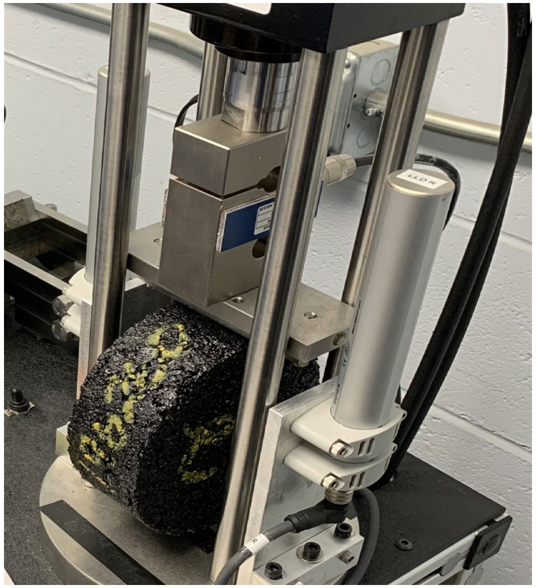
December 5, 2022

Casey Nash, P.E.

Asphalt Pavement Engineer

Cracking Tests

AMPT (Sapp)	IDT-CT (CTI)
Sapp ≥ 8	CTI ≥ 150



Cracking Tests

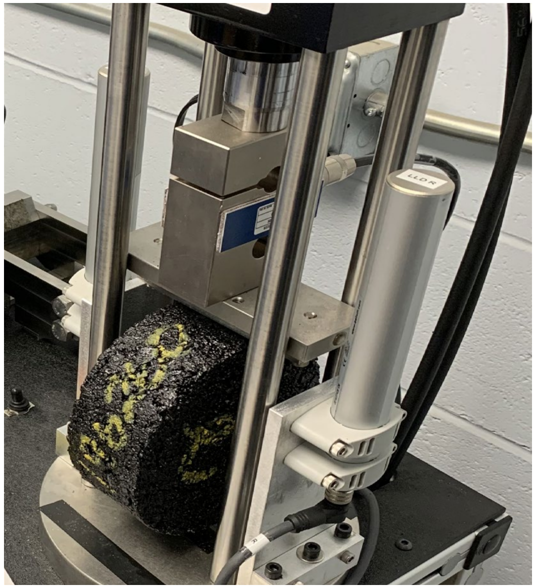
AMPT (Sapp)
Sapp ≥ 8

- > Material
- > Fabrication
- > Test time
- > Training
- > Cost

Cracking Tests

- < Material
- < Fabrication
- < Test time
- < Training
- < Cost

IDT-CT (CTI)
CTI ≥ 150

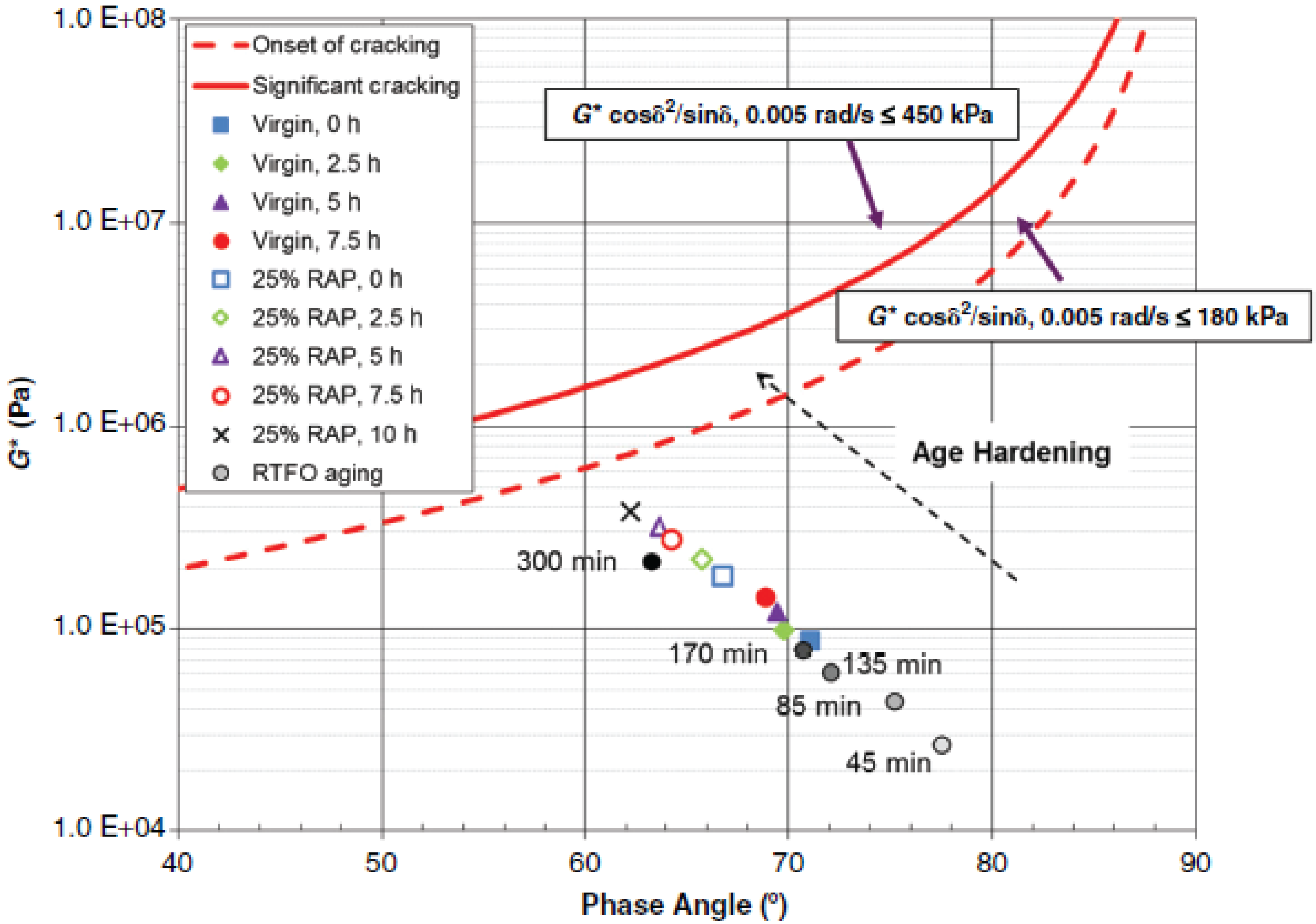


Aging

- Lab
  - Short-term aging
- Plant
  - Reheated
- ASTM D8225-19

IDT-CT (CTI)
CTI ≥ 150

Aging



Transportation Research Record Journal of the Transportation Research Board. 2573.
Effect of Silo Storage Time on the Characteristics of Virgin and RAP Asphalt Mixtures 80.

Polymer Modification

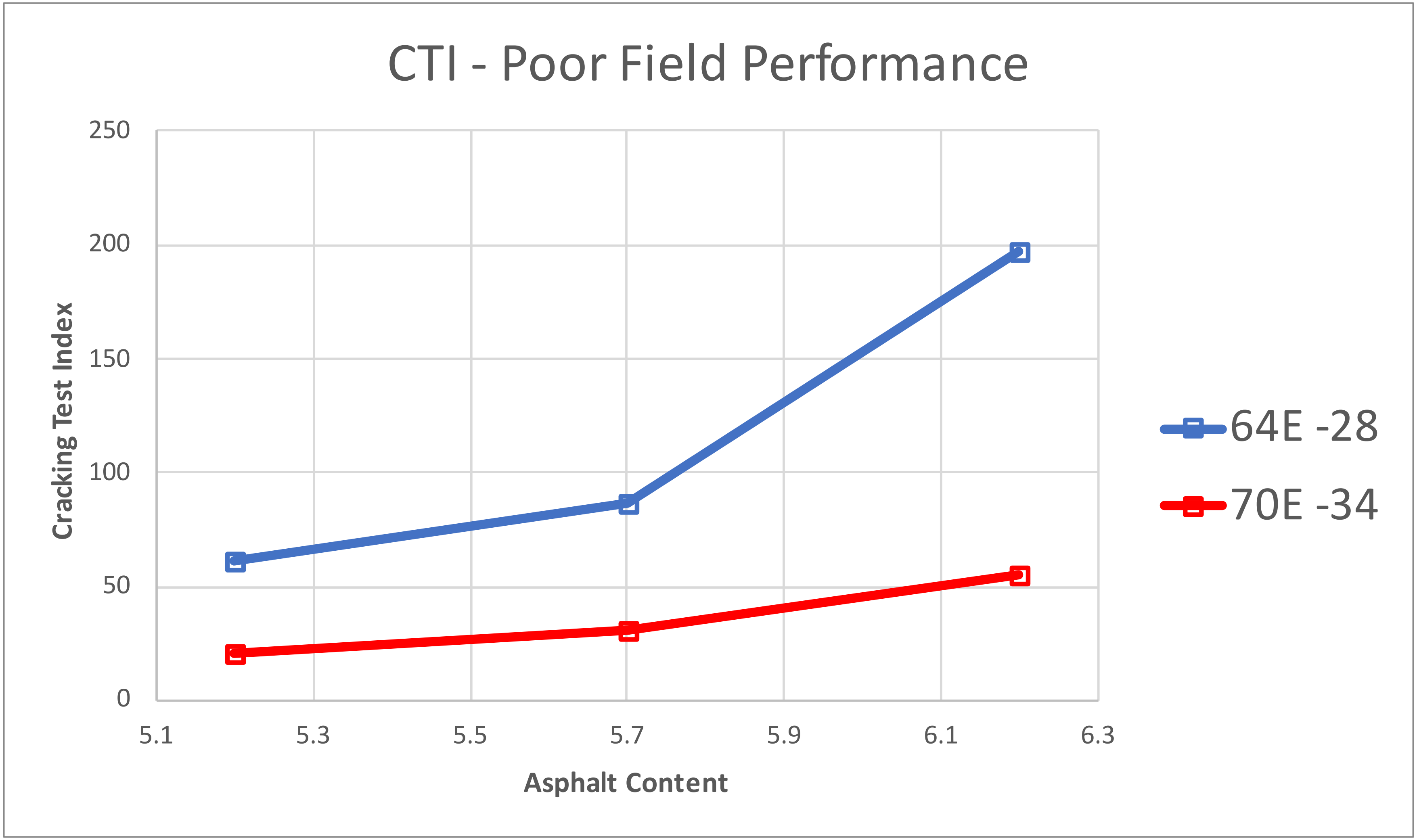
- Assumption
  - Adding polymer to asphalt binder improves crack resistance
- Reality
  - As a blanket statement this is a false assumption.

Polymer Modification

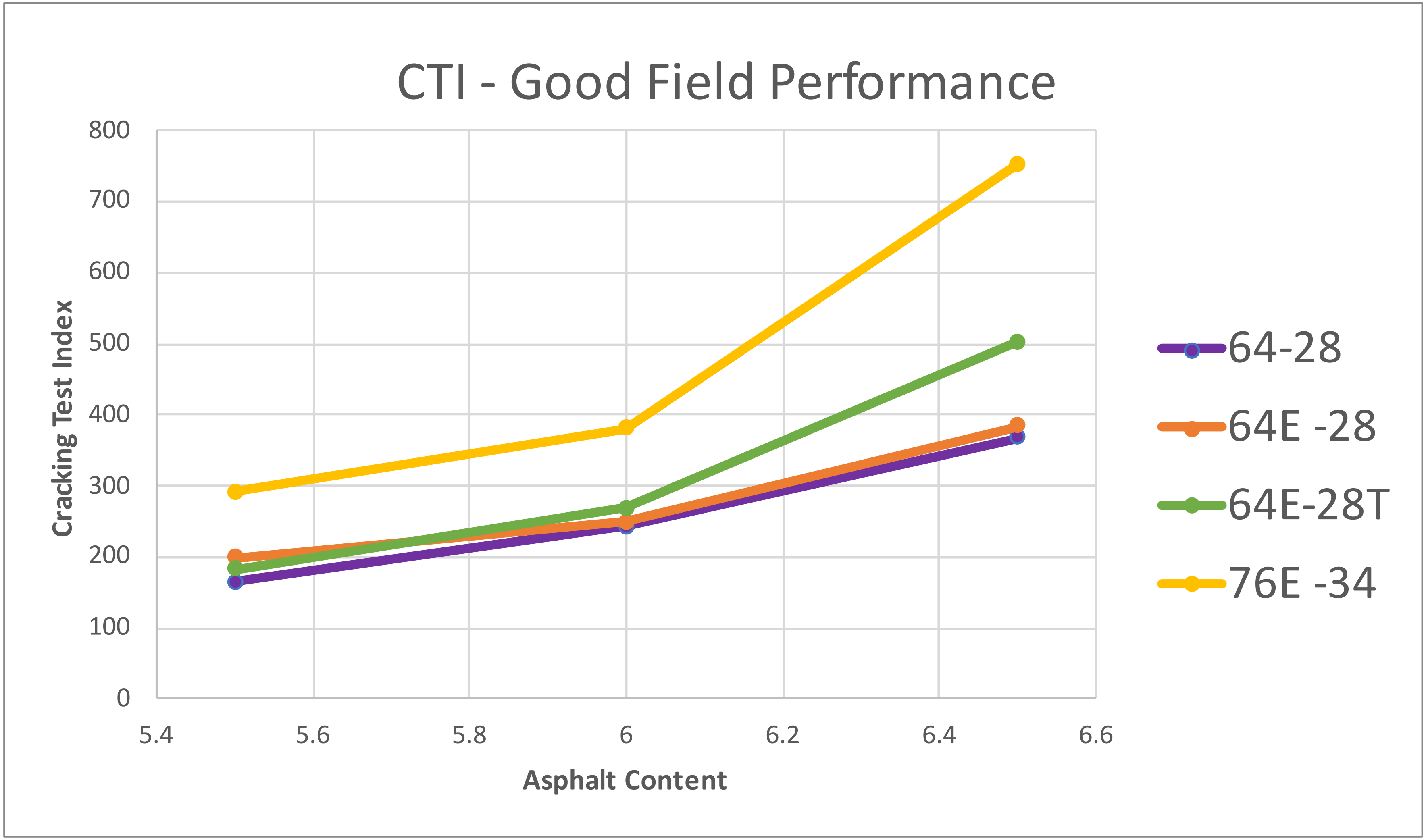
- "Field tests show that all PMAs in general have improved the rutting resistance of asphaltic concrete mix."
- "However, with respect to cracking, polymers that used 85 to 100 pen base asphalt in these test sections have more cracking than the control sections."

Transportation Research Record Journal of the Transportation Research Board. 1545.
Polymer-Modified Asphalt Pavements in Ontario: Performance and Cost-Effectiveness 151-160.

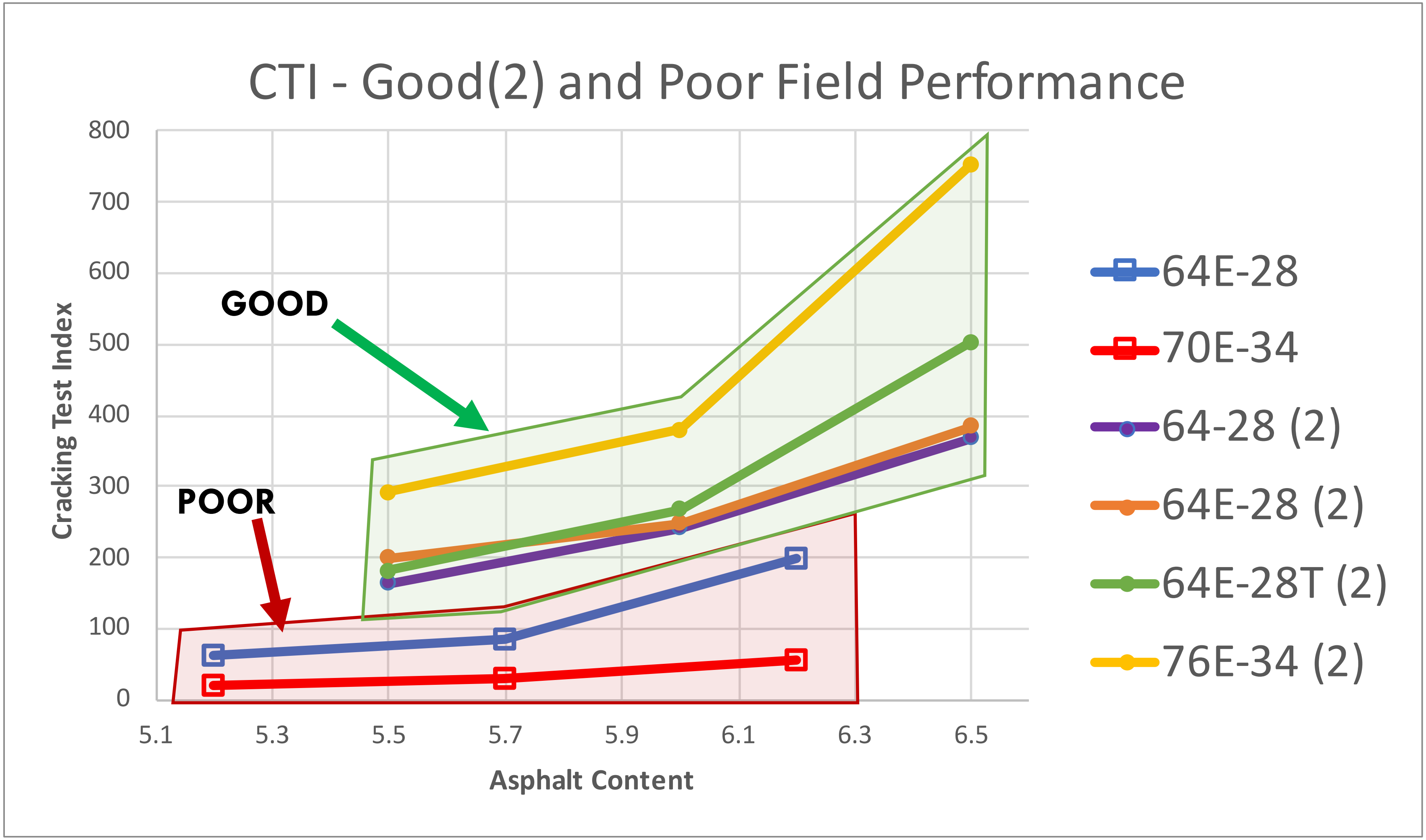
CTIndex – Mix 1



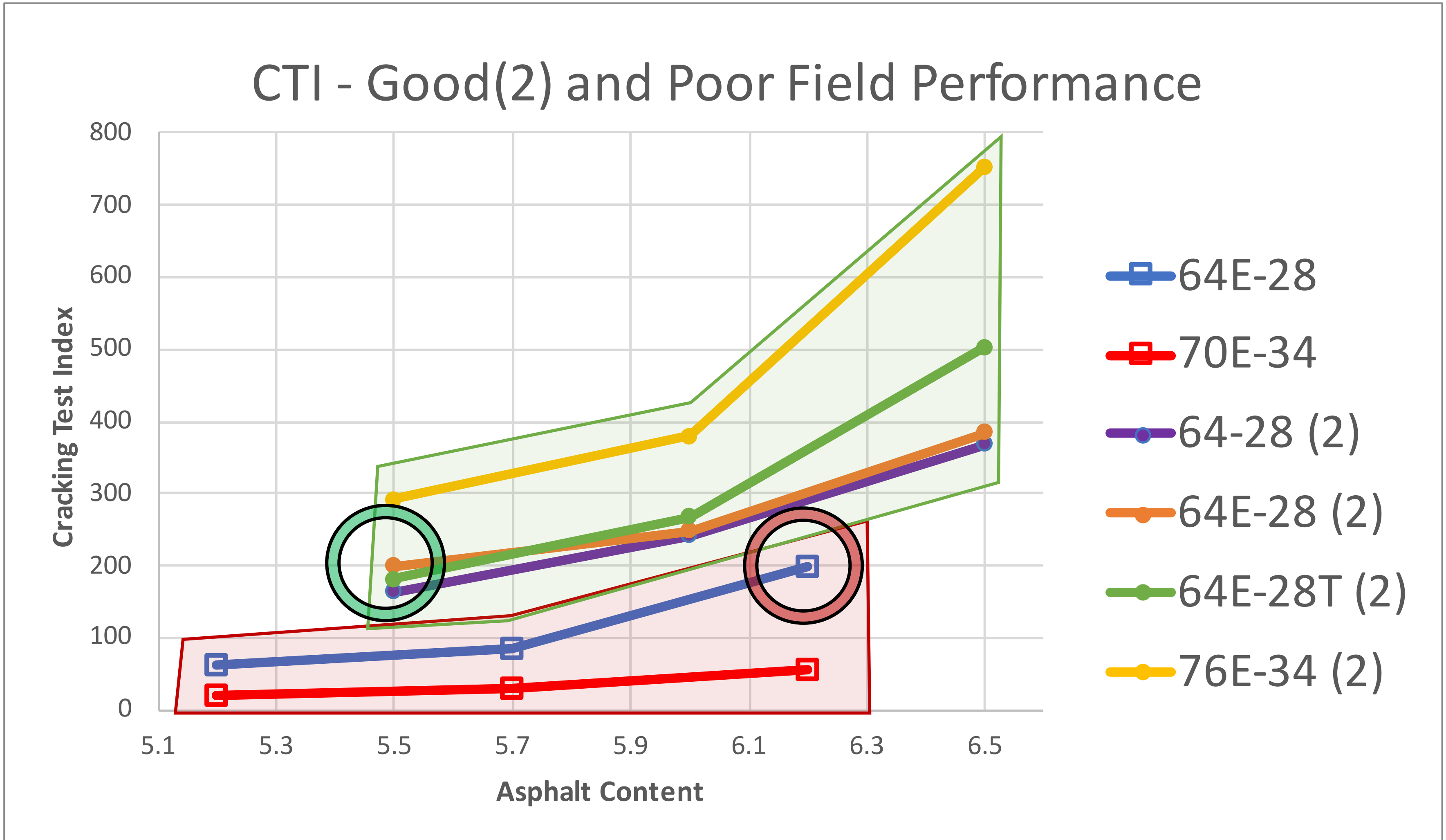
CTIndex – Mix 2



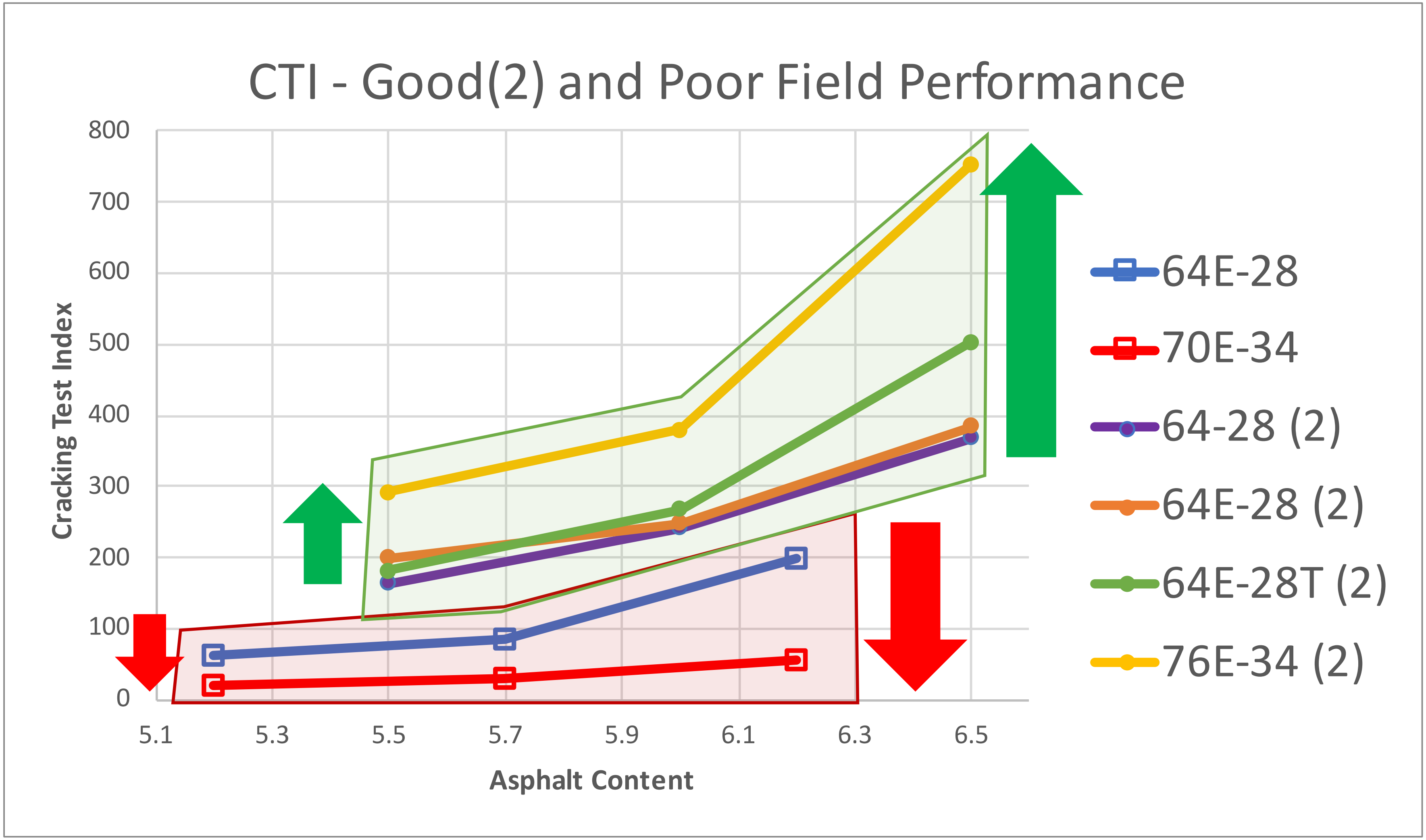
CTIndex – Lab Investigation



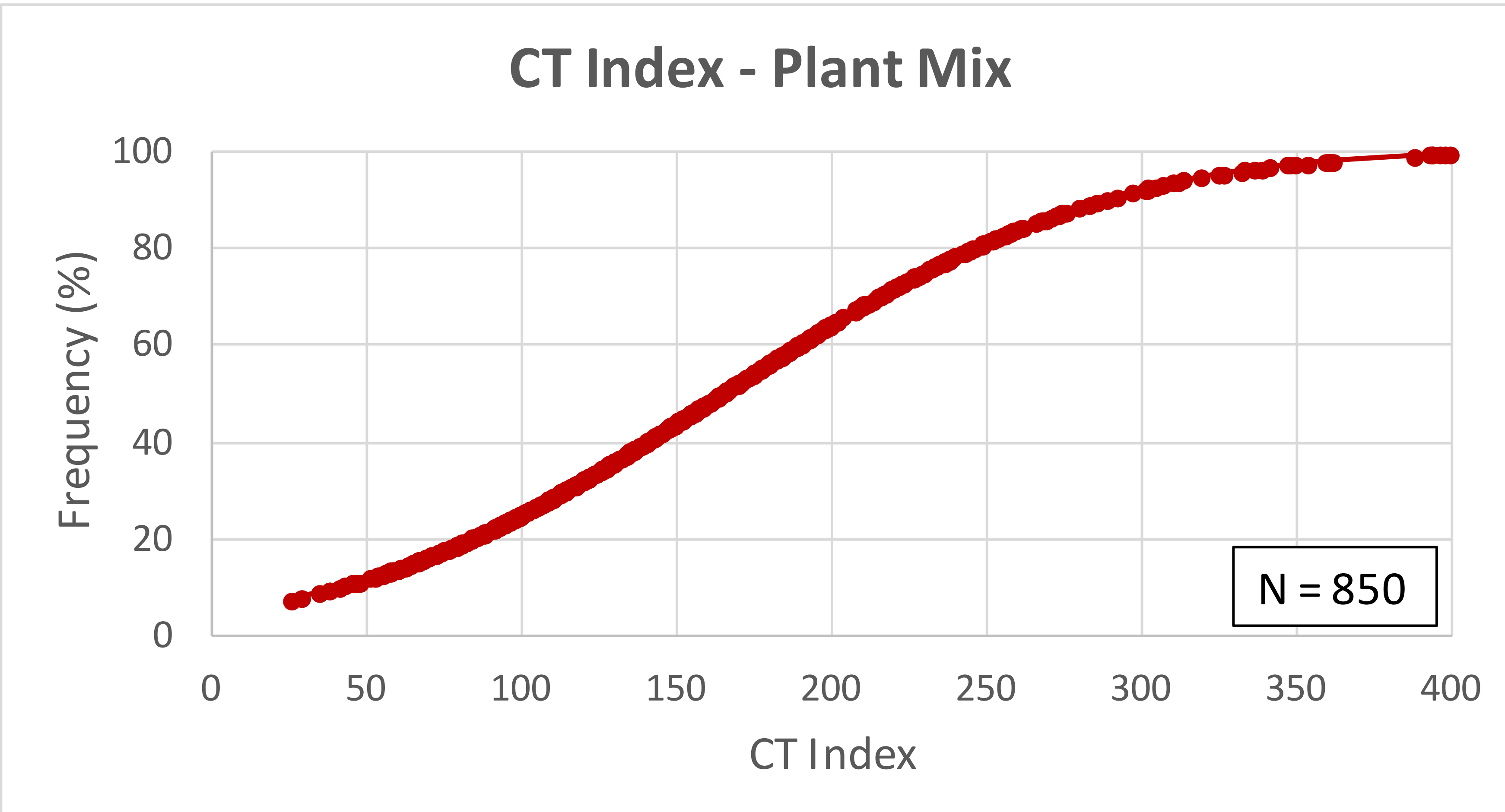
CTIndex – Lab Investigation



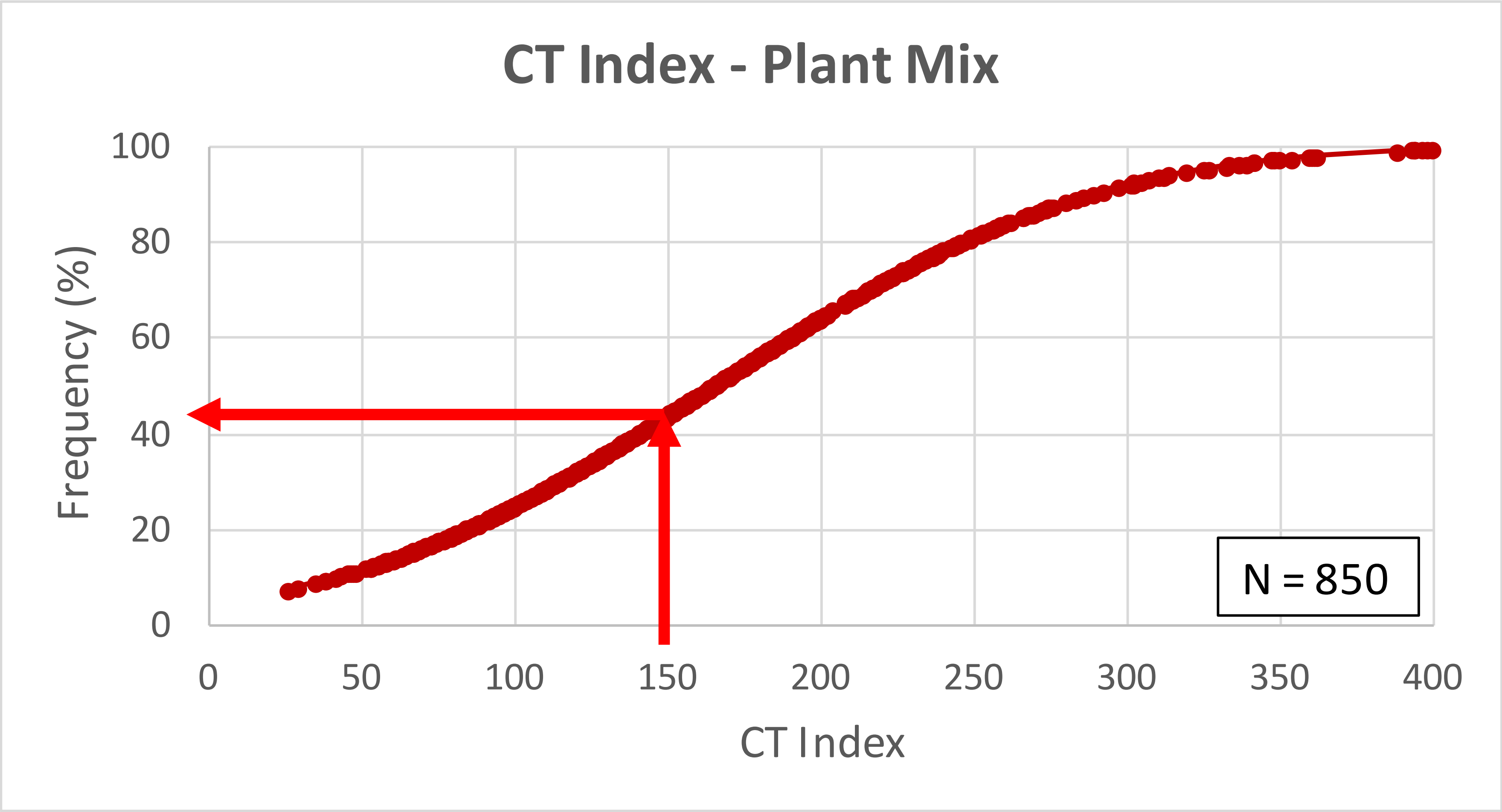
CTIndex – Lab Investigation



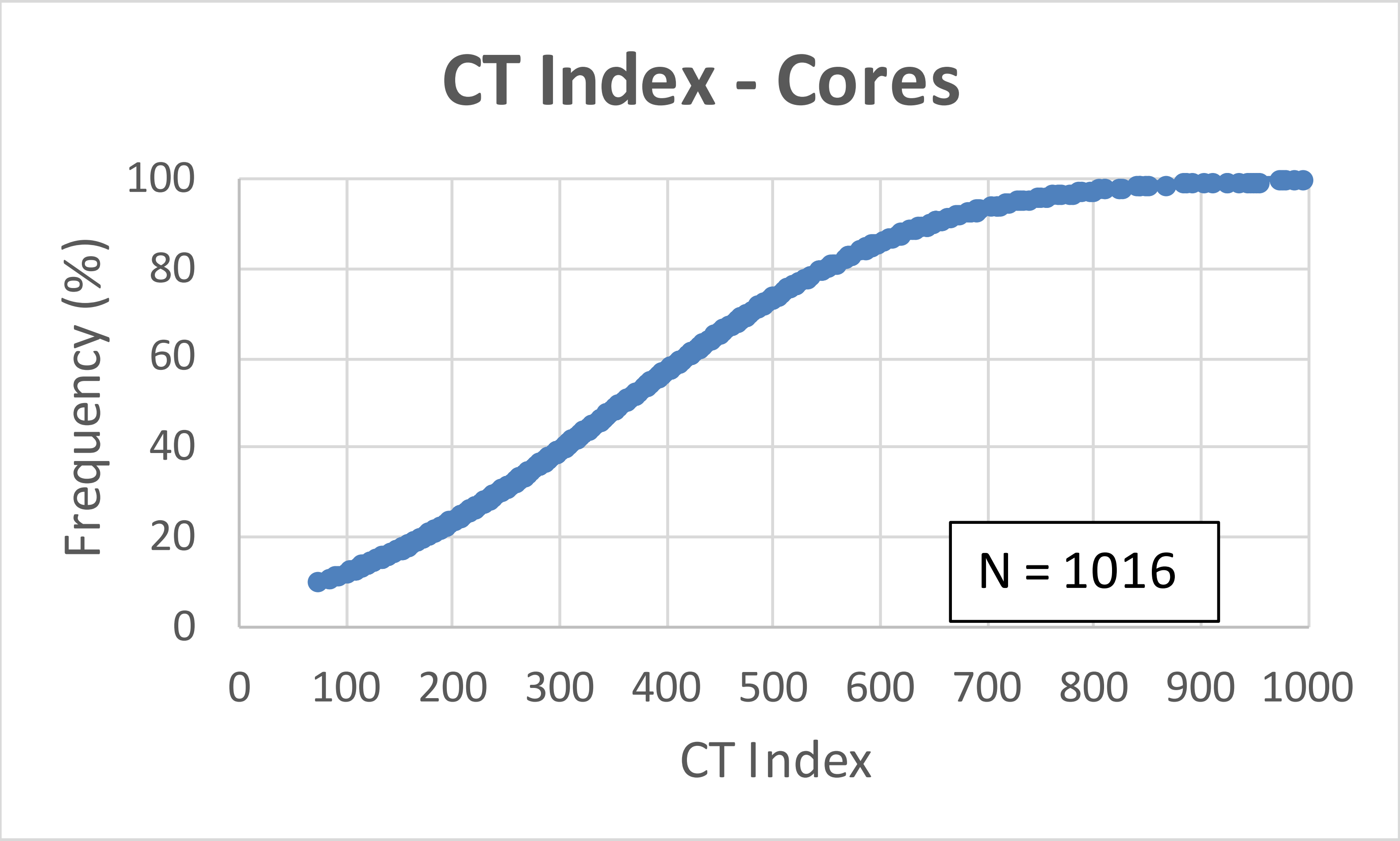
CTIndex – Plant Mix Benchmarking



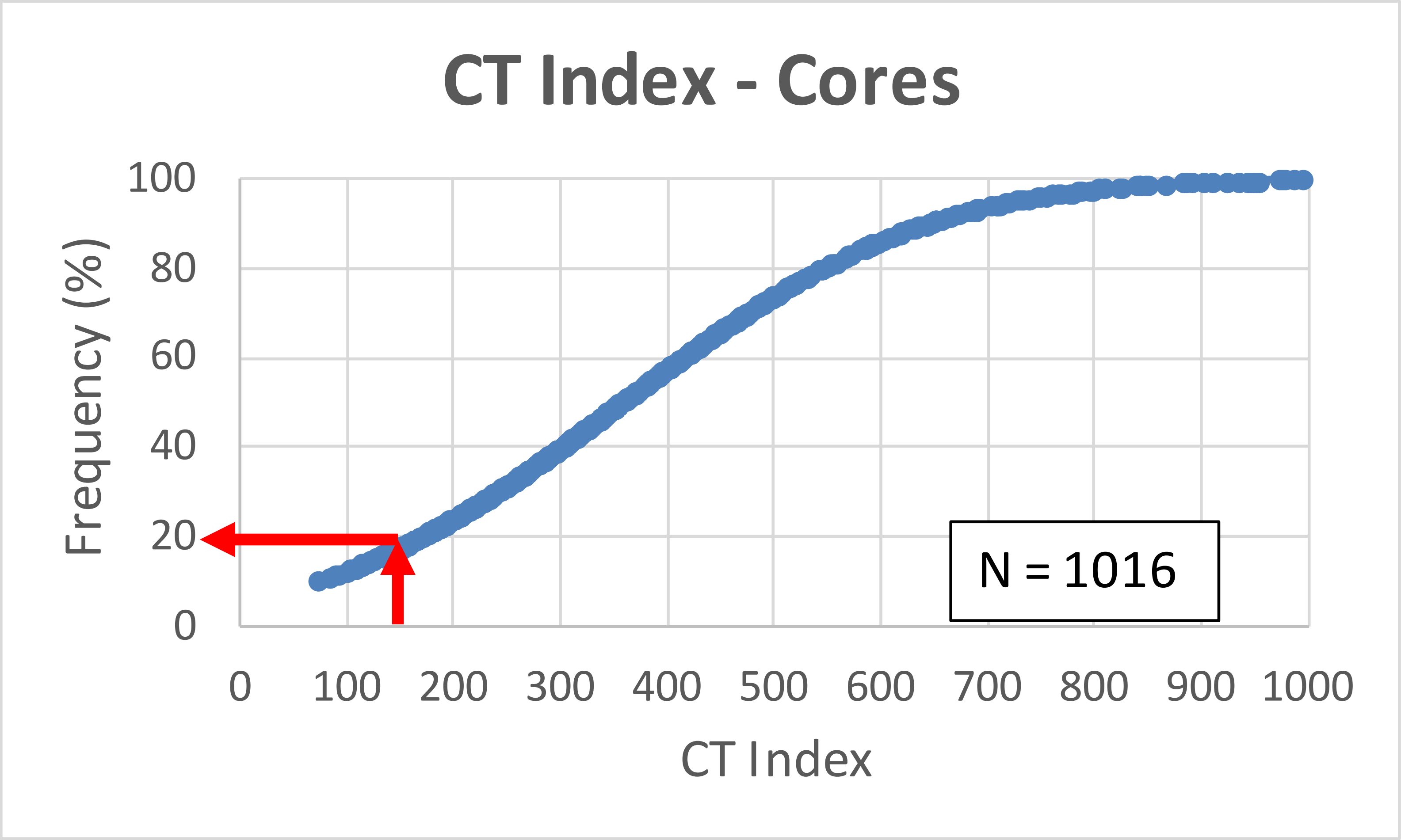
CTIndex – Plant Mix Benchmarking



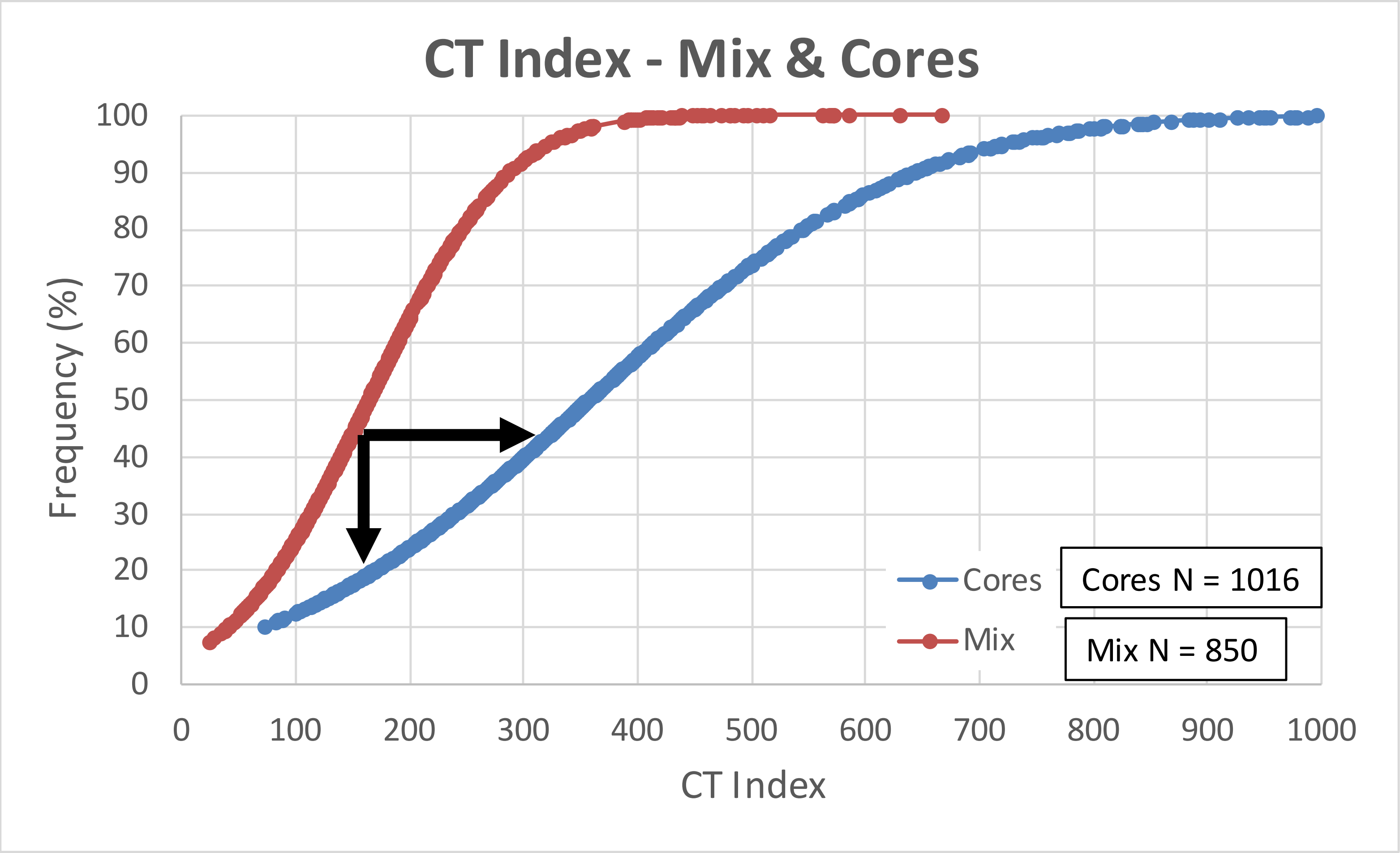
CTIndex – Core Benchmarking



CTIndex – Core Benchmarking



CTIndex – Mix & Cores



Summary

- Many state agencies are focusing on simpler cracking tests for sustainable implementation
- There are pros and cons to short and long-term aging but short-term doesn't seem to be changing
- Polymer modification does not always improve crack resistance
- Initial assessment of cores resulted in approximately double the CT index of the same frequency of mix samples.

Thank you for the opportunity.

Any Questions?

Casey Nash, PE
Asphalt Pavement Engineer
Casey.B.Nash@maine.gov
207-592-7372

Today’s presenters

Tom Bennert
bennert@soe.rutgers.edu
Rutgers University

Fujie Zhou
f-zhou@tti.tamu.edu
Texas A&M Transportation Institute

Casey Nash
Casey.B.Nash@maine.gov
Maine Department of Transportation

Upcoming events for you

December 15, 2022

TRB Webinar: Measuring and Managing Fare Evasion

January 8-12, 2023

TRB Annual Meeting

https://www.nationalacademies.org/trb/events

Register for the 2023 TRB Annual Meeting

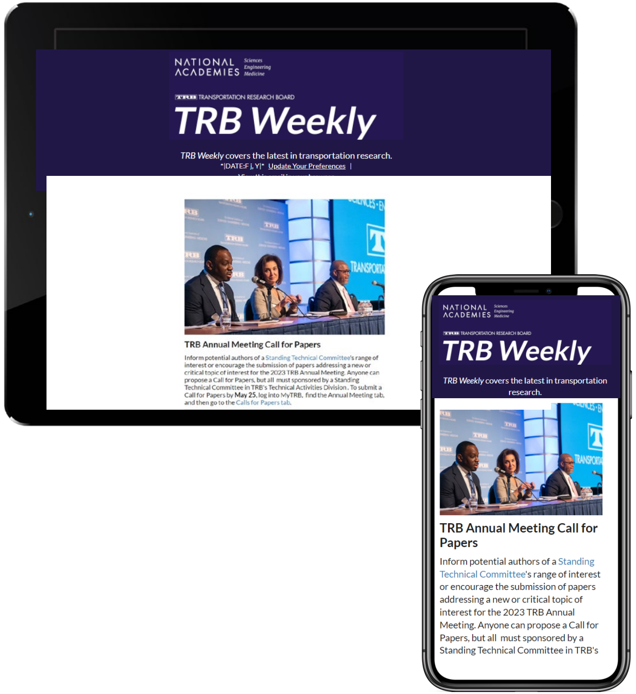
https://www.trb.org/AnnualMeeting/Registration.aspx

Subscribe to *TRB Weekly*

If your agency, university, or organization perform transportation research, you and your colleagues need the *TRB Weekly* newsletter in your inboxes!

Each Tuesday, we announce the latest:

- RFPs
- TRB's many industry-focused webinars and events
- 3-5 new TRB reports each week
- Top research across the industry



Spread the word and subscribe!
https://bit.ly/ResubscribeTRBWeekly

Discover new TRB Webinars weekly

Set your preferred topics to get the latest listed webinars and those coming up soon every Wednesday, curated especially for you!

https://mailchi.mp/nas.edu/trbwebinars

And follow #TRBwebinar on social media

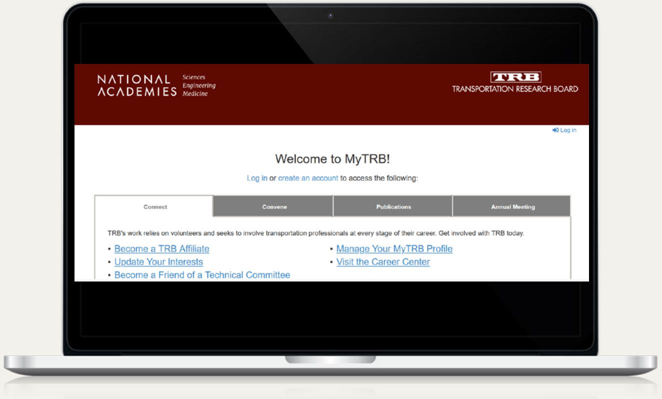
@NASEMTRB

@NASEMTRB

Transportation Research Board

Get involved

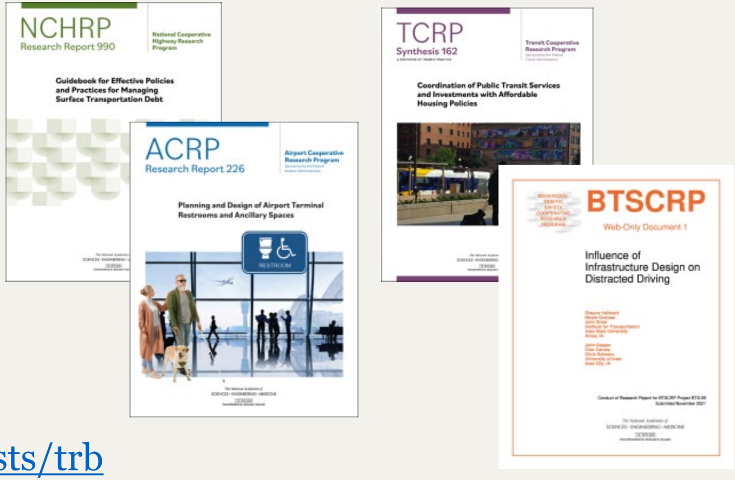
https://www.nationalacademies.org/trb/get-involved



- **Become a Friend of a Standing Technical Committee**

  Network and pursue a path to Standing Committee membership

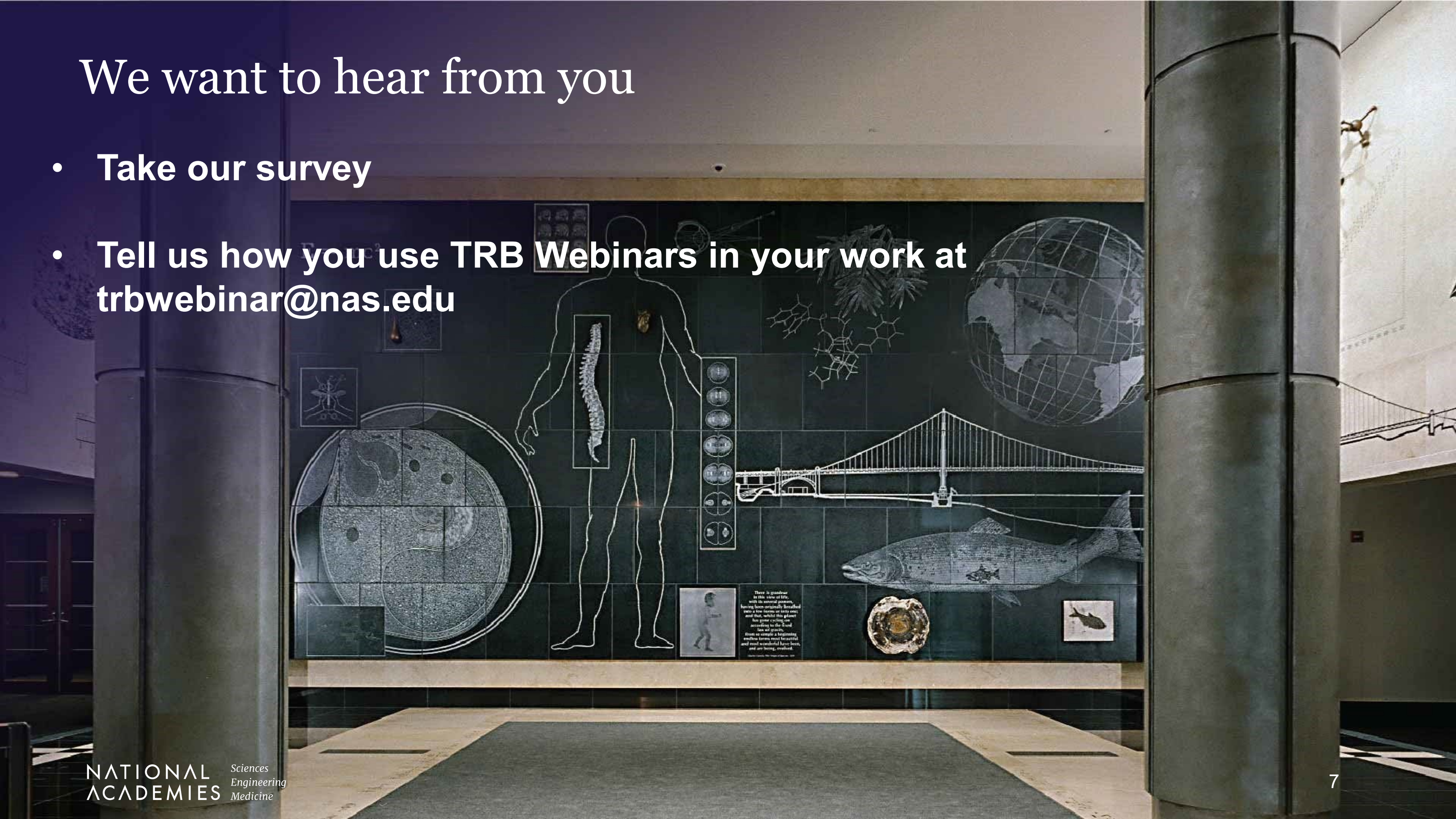
- **Work with a CRP**



- **Listen to our podcast**

Apple Podcasts | Spotify | Google Podcasts | Overcast | Castbox | Pocket Casts | RSS feed

https://www.nationalacademies.org/podcasts/trb



We want to hear from you

- **Take our survey**

- **Tell us how you use TRB Webinars in your work at trbwebinar@nas.edu**