Testing Protocols to Ensure Mix Performance w/ High RAP and RAS

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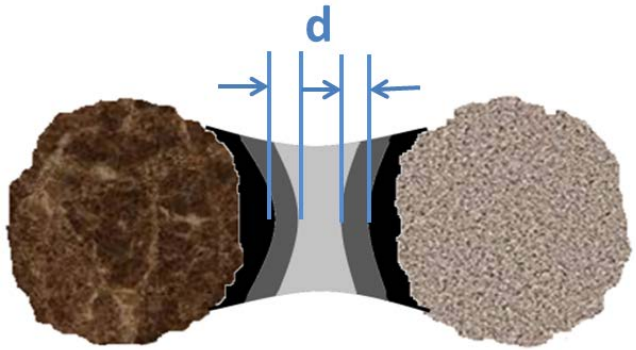
Challenges with RAP/RAS

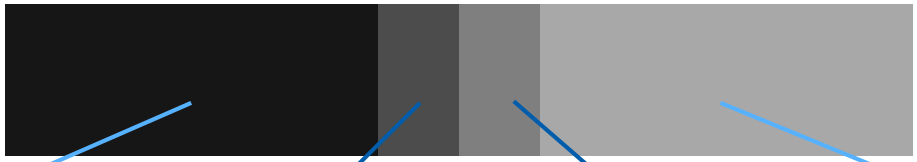
- SuperPave was developed for neat materials
- More recycled materials are used in HMA – moving away from specifying virgin components – especially asphalt PG grades in final mix
- Currently recycle usage is allowed by method specifications intended to limit risk of cracking by ABR limits and grade bumping, not actual mix performance
- Fatigue cracking issue: stiffer mixes with high ABR may exhibit early fatigue cracking
- Thermal/Block cracking issue: Stiffer mixes have reduced relaxation potential

Challenges (RAB/RAS Binder)

- Shingle asphalt is air blown to harden asphalt (*PG 112+02*) then additional aging on the roofs
- RAP AC can be hard or soft – depends on project(s) milled
- Counteracting binder selection of virgin binder becomes arbitrary
- Neat asphalt blending with RAP and RAS for final mix is not well understood

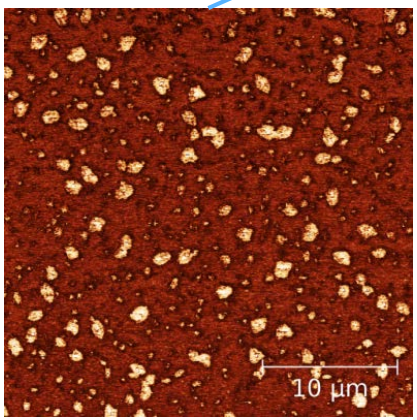
Measurement Scheme at a Glance





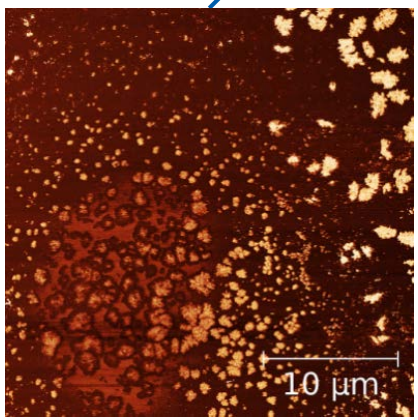
Scan size: 30µm

A



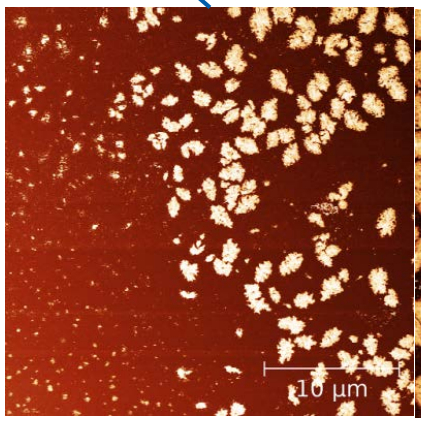
A : RAP-bitumen

B



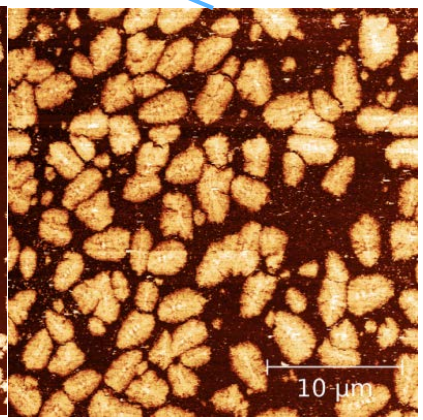
B : Blended zone

C



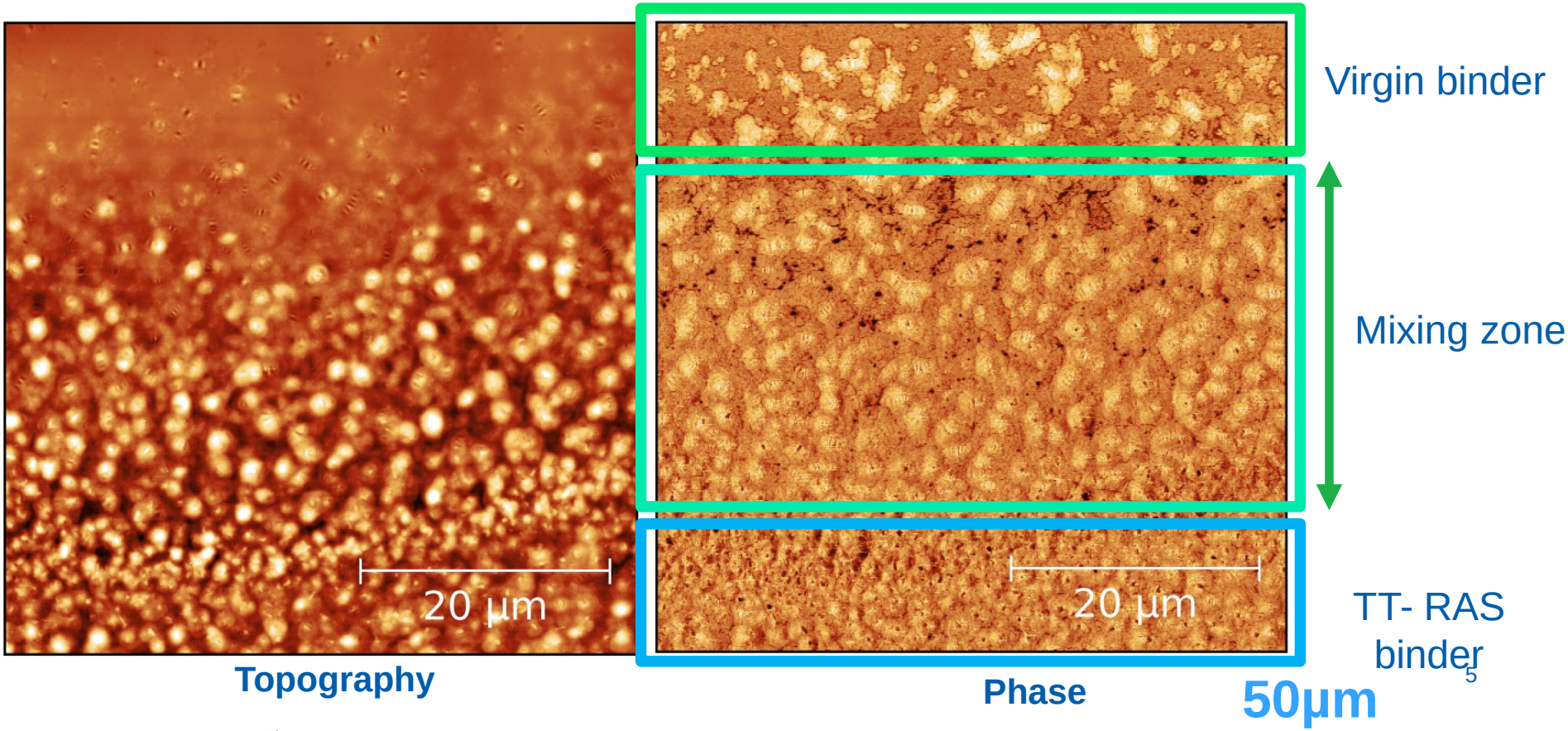
C : Transition zone

D



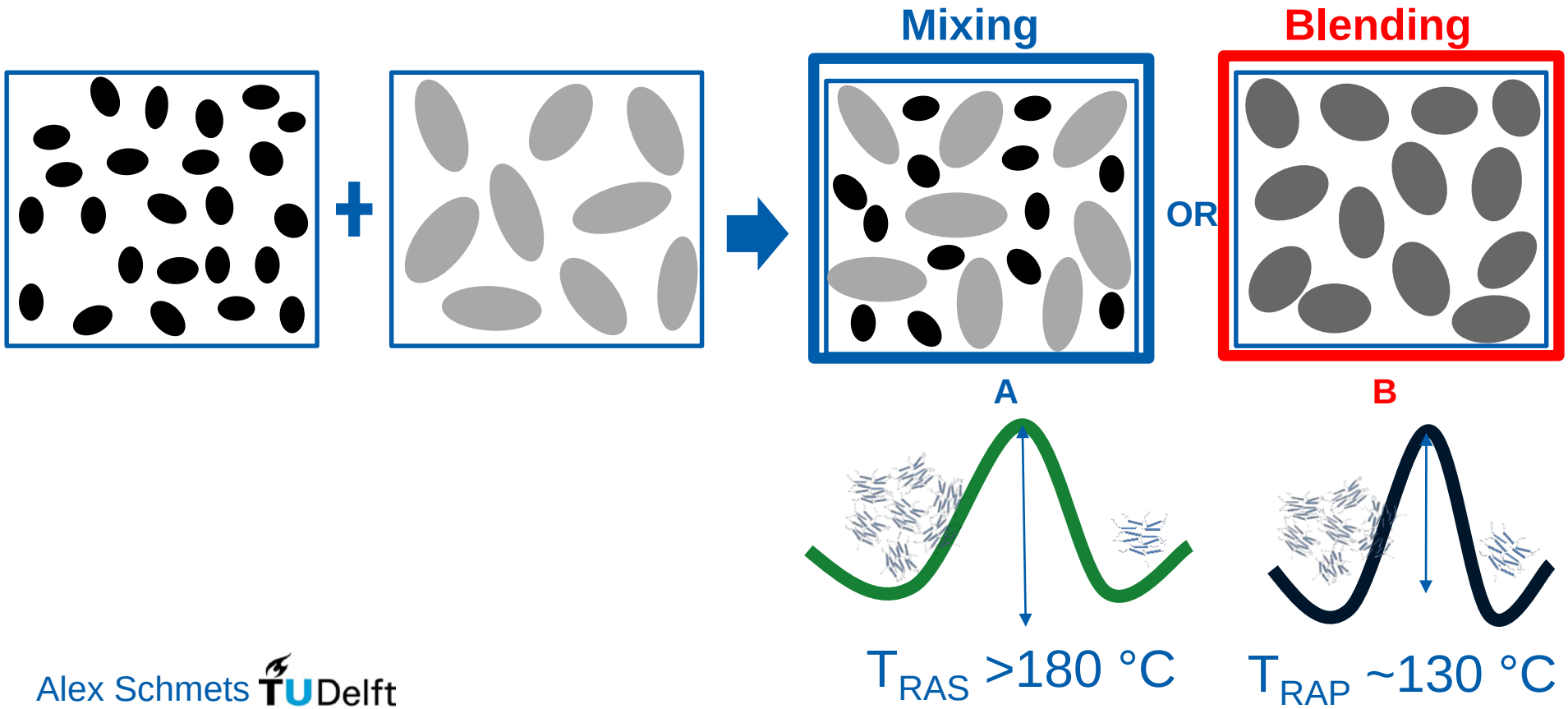
D : Virgin bitumen

RAS and Virgin Binder Interface

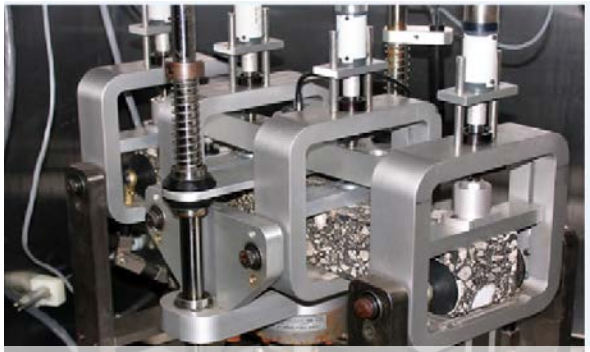


Comparing RAP & RAS 'Rejuvenation'

- B: RAP-binder/ Virgin-bitumen
- A: RAS-binder/ Virgin-bitumen

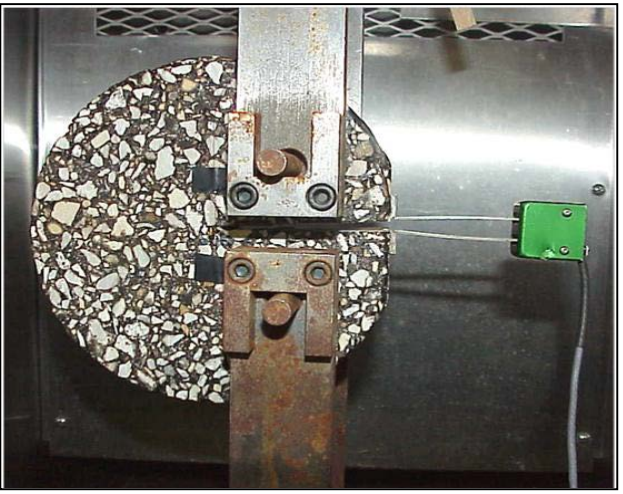


Mixture Tests Available



Beam Fatigue Test

Push-pull Fatigue



DCT (ASTM D7313)

SCB (AASHTO TP105)

Texas Overlay Test

Test Method Selection Criteria

- Significant and meaningful spread in test output
- Correlation to independent tests and engineering intuition
- Correlation to field performance
- Applicability and seamless implementation

Semi-Circular Bending Test

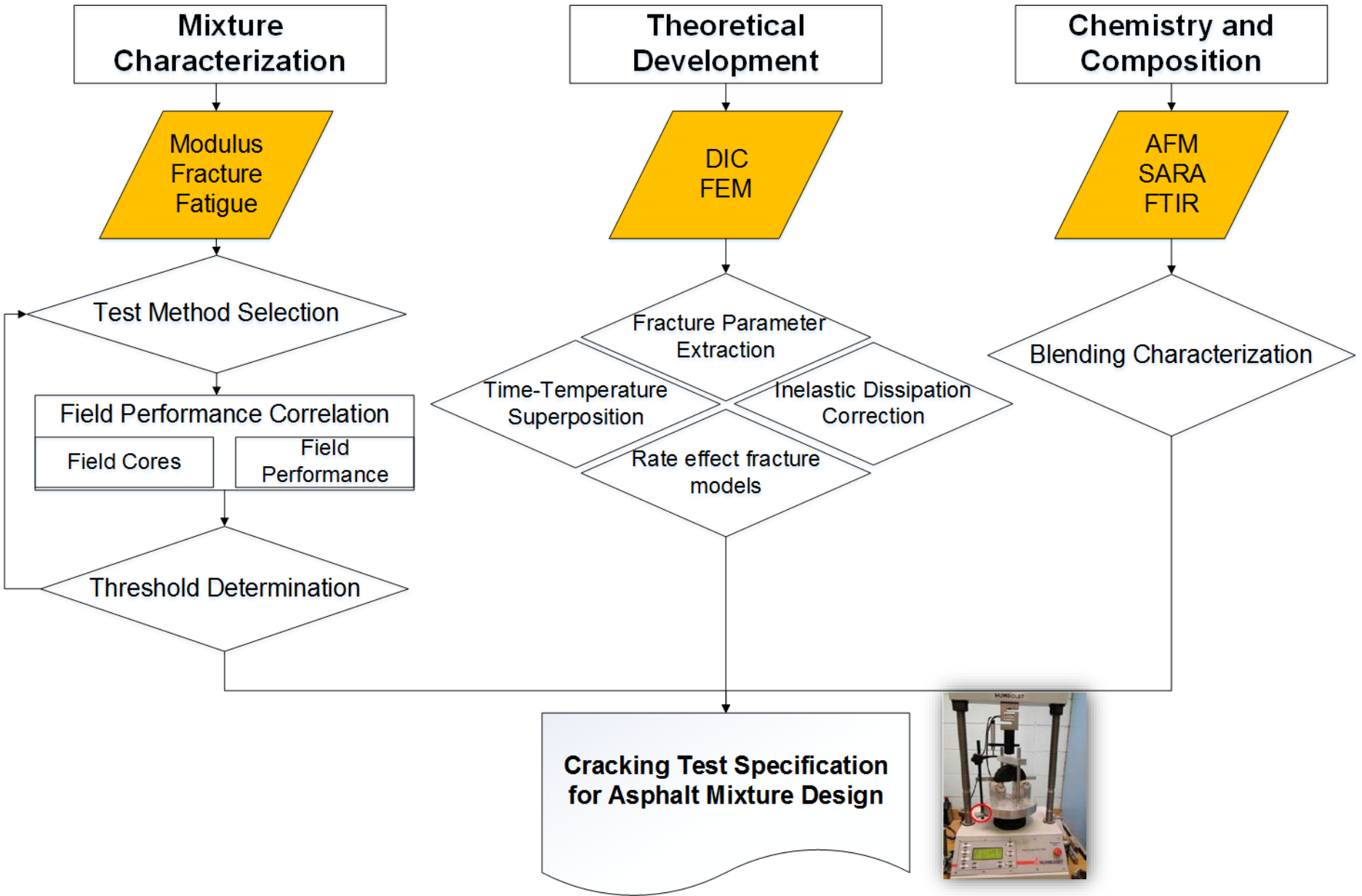
- Relies on simple three point bending
- Easy specimen preparation
- Can use AASHTO T283 equipment
- Repeatability

Research Approach

Parameter	Variables
Material Source	Plant Mixes, Lab-Mixes, Field Cores
N-Design	N30, N50, N70, N80, N90
Nominal Maximum Aggregate Size	4.75 mm, 9.5 mm, 12.5 mm, 19.0 mm
Asphalt Binder	PG52-28, PG58-22, PG58-28, PG64-22, PG70-22, PG70-28, PG76-22
Recycled Materials	RAP, RAS, Recycled Concrete, and Steel Slag
Asphalt Binder Ratio	0 to 60
RAP Content (%)	0 to 53
RAS Content (%)	0 to 8.5

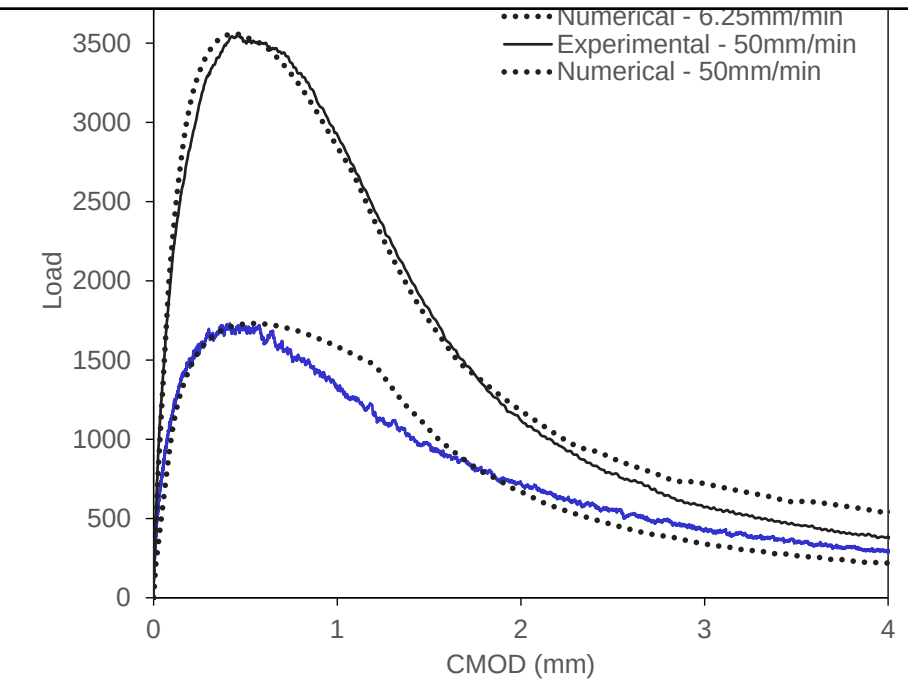
- **Assessment of variety of plant mixes, lab design mixes, and field cores**
- **Correlation to other tests (modulus and fatigue)**
- **Theoretical and numerical evaluation**

Overall Framework

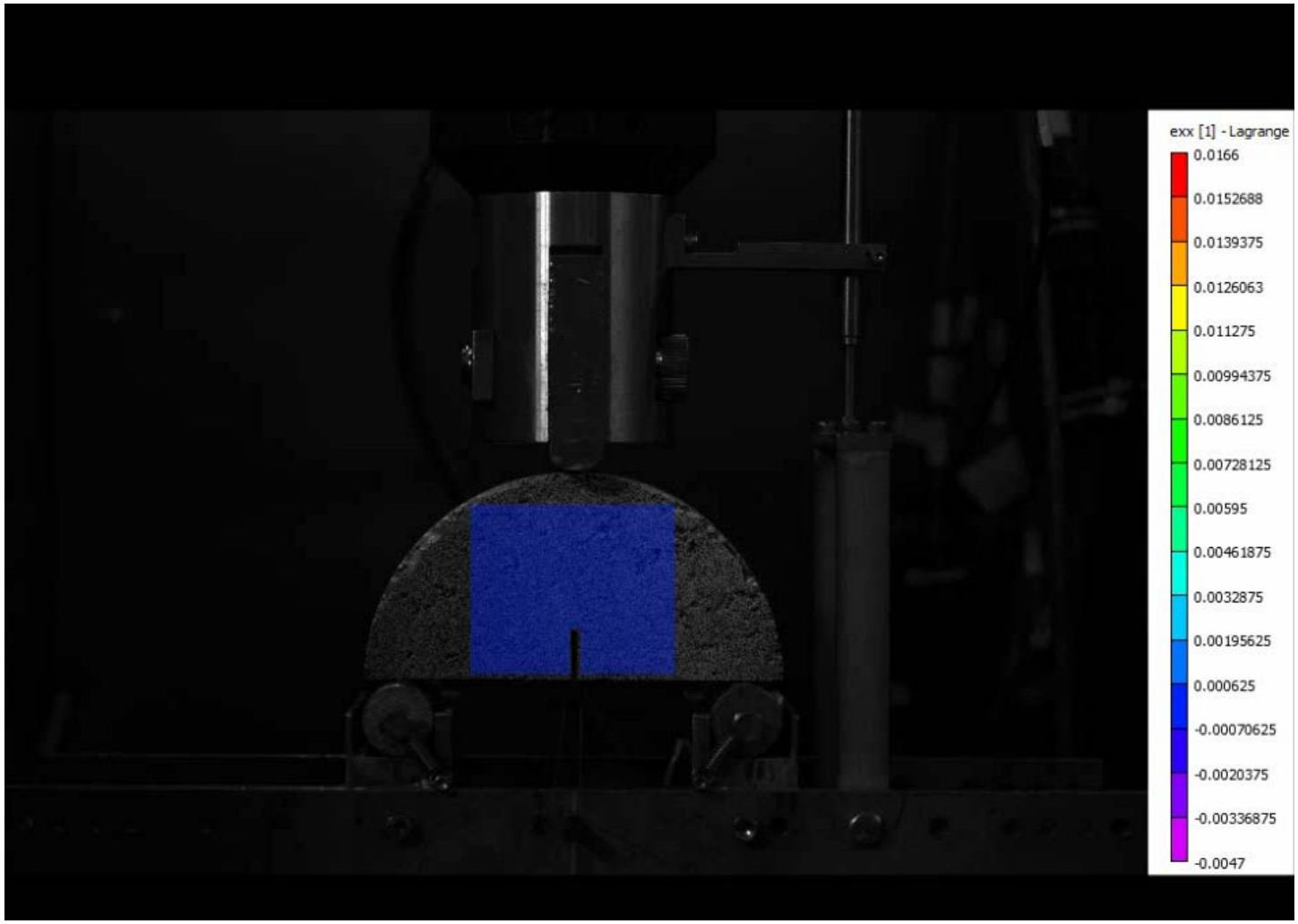


FEM Results

- FEM simulations of N80-25 mix



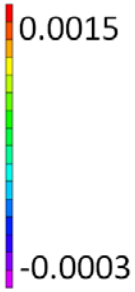
Fracture Process Zone

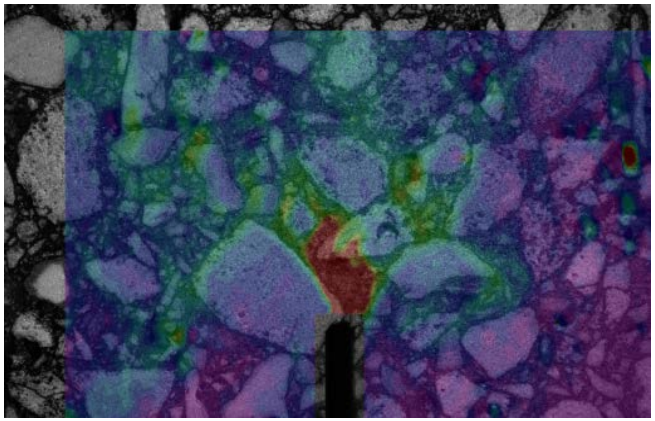


Fracture Process Zone

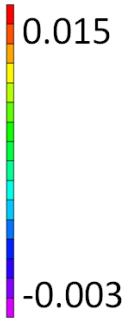
N90 Control (0% RAS)

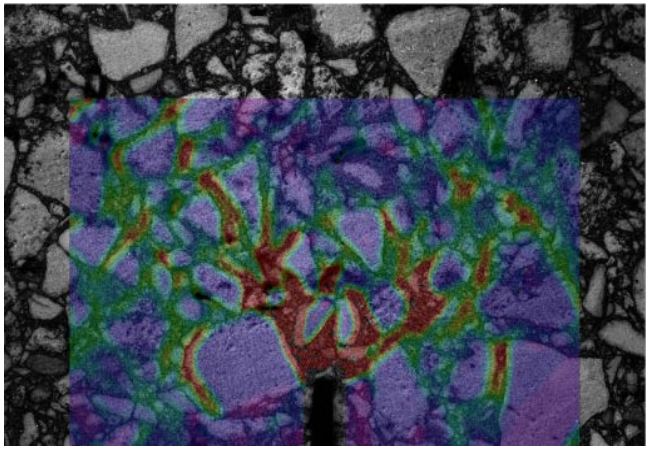
-12°C @ 0.7 mm/min





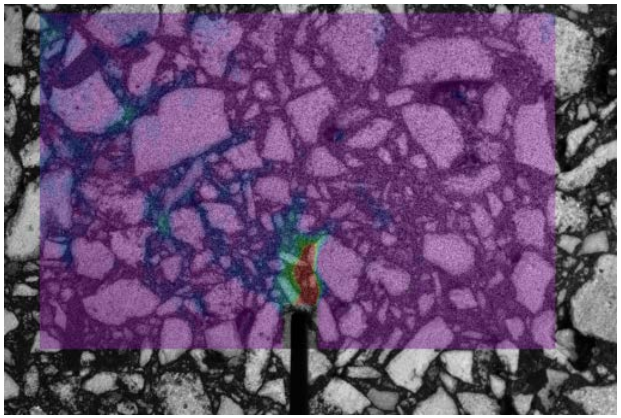
25°C @ 50mm/min



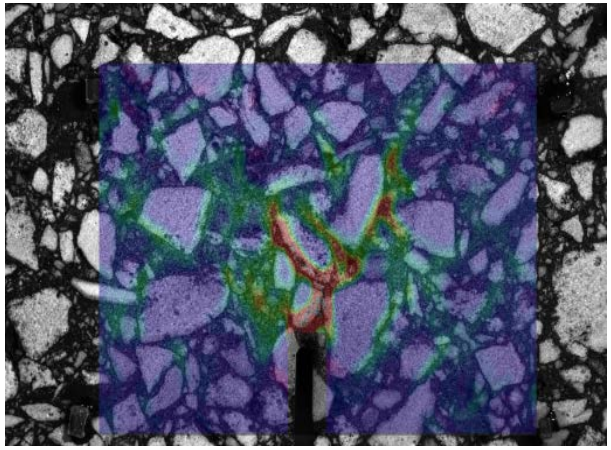


N90 30% ABR (7% RAS)

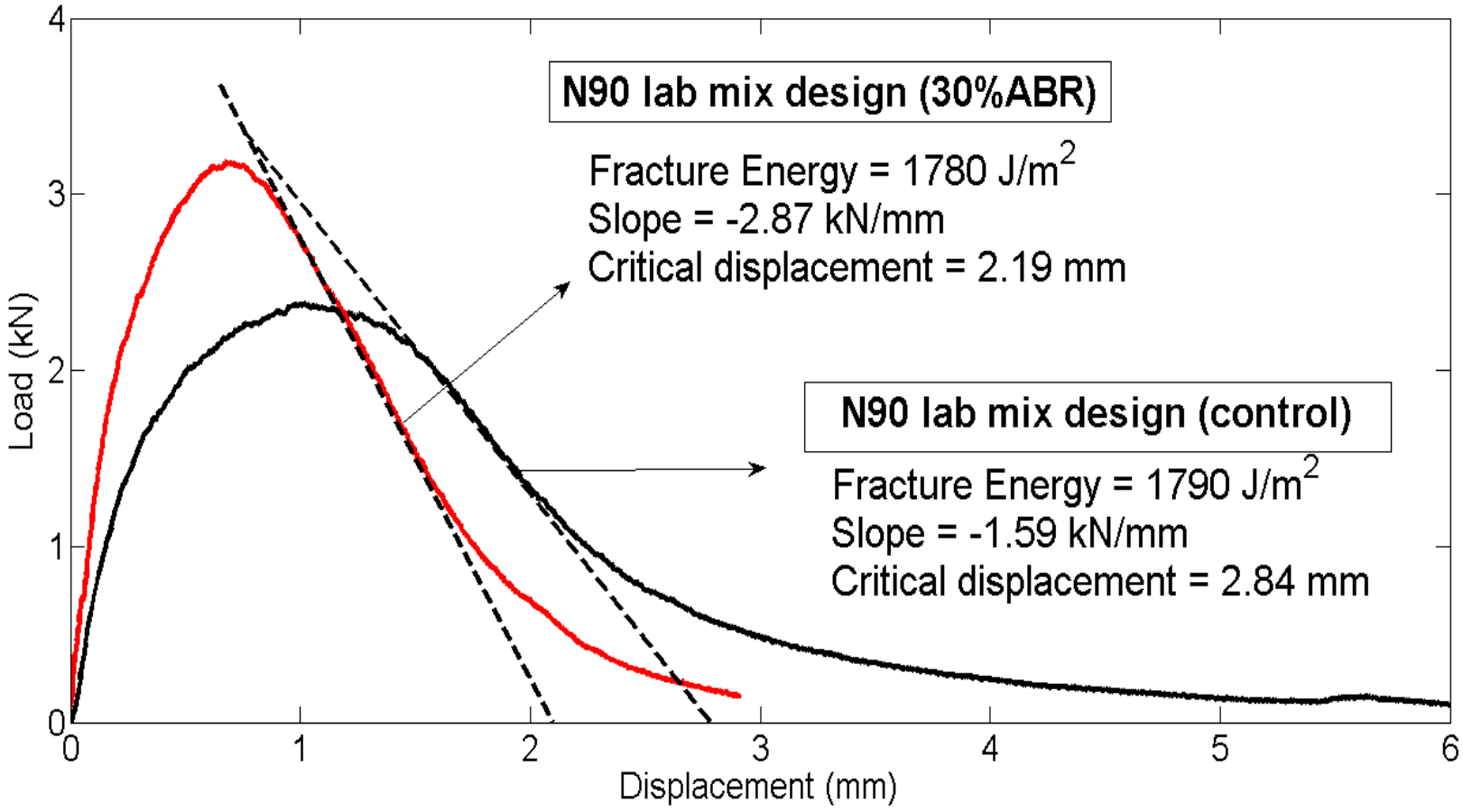
-12°C @ 0.7 mm/min



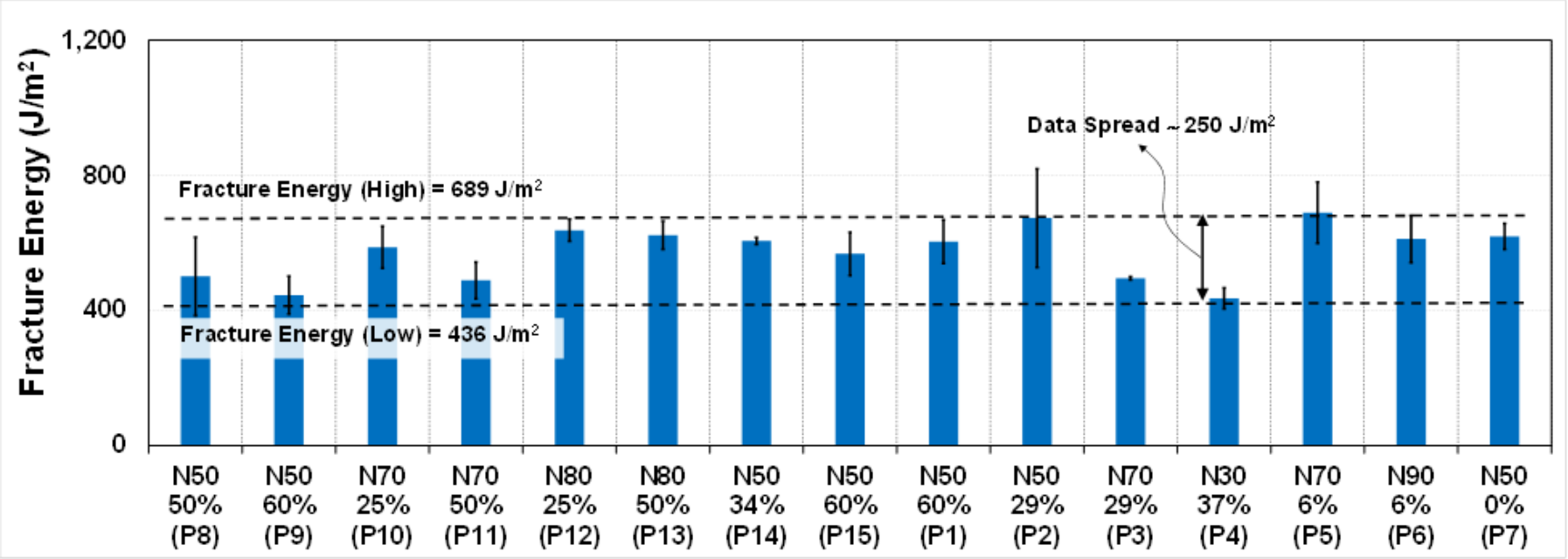
25°C @ 50mm/min



SCB Fracture Results

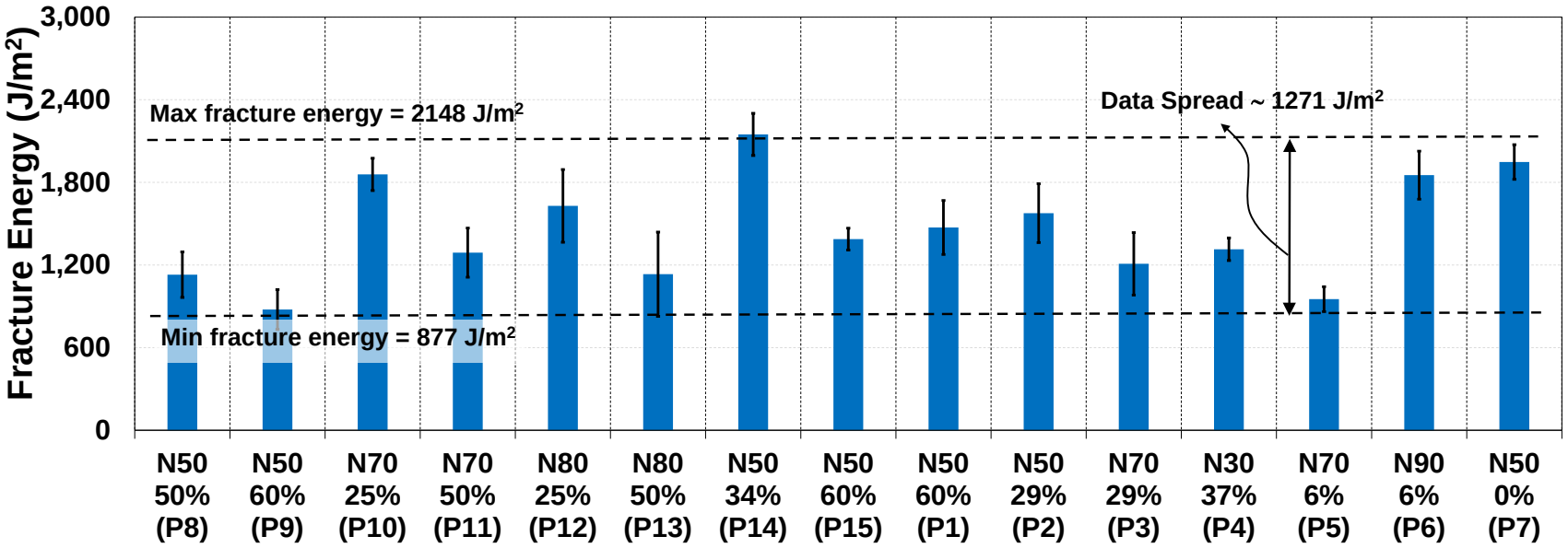


Establishment of Test Temperature and Loading Rate



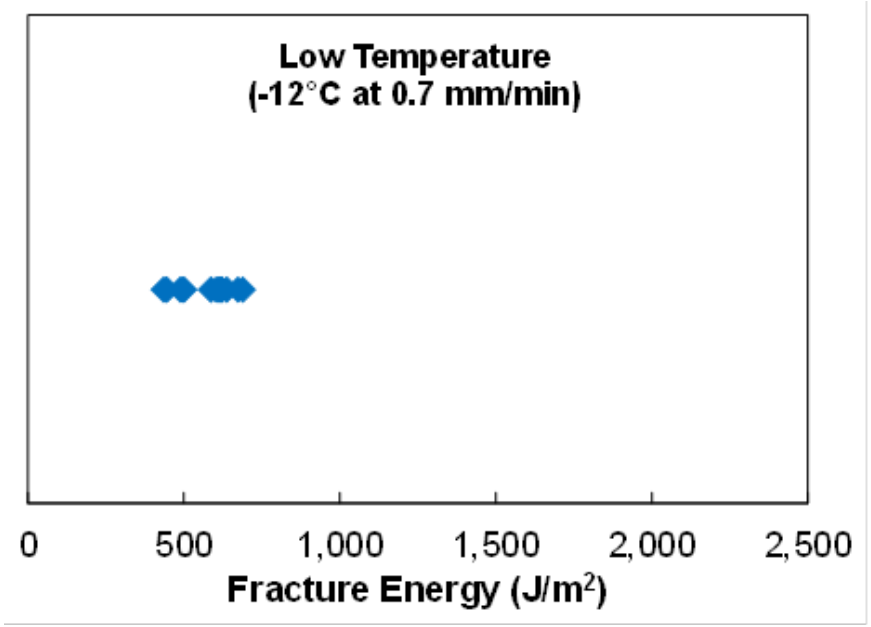
- SCB fracture test results at -12°C
- Limited data spread

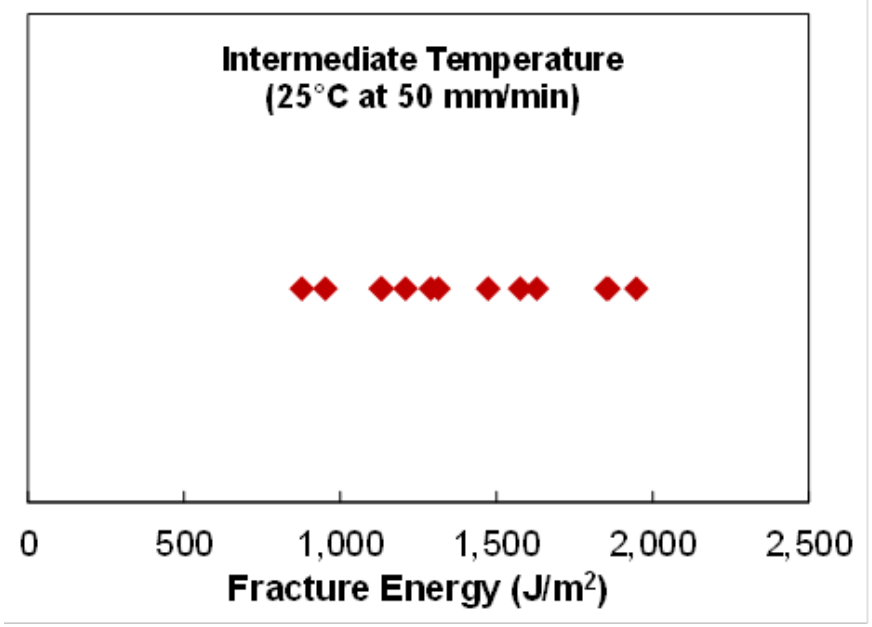
Establishment of Test Temperature and Load Rate



- SCB fracture energy results for the same mixes at 25 °C using displacement control at 50 mm/min
- Significant spread in fracture energy

Establishment of Test Temperature and Load Rate



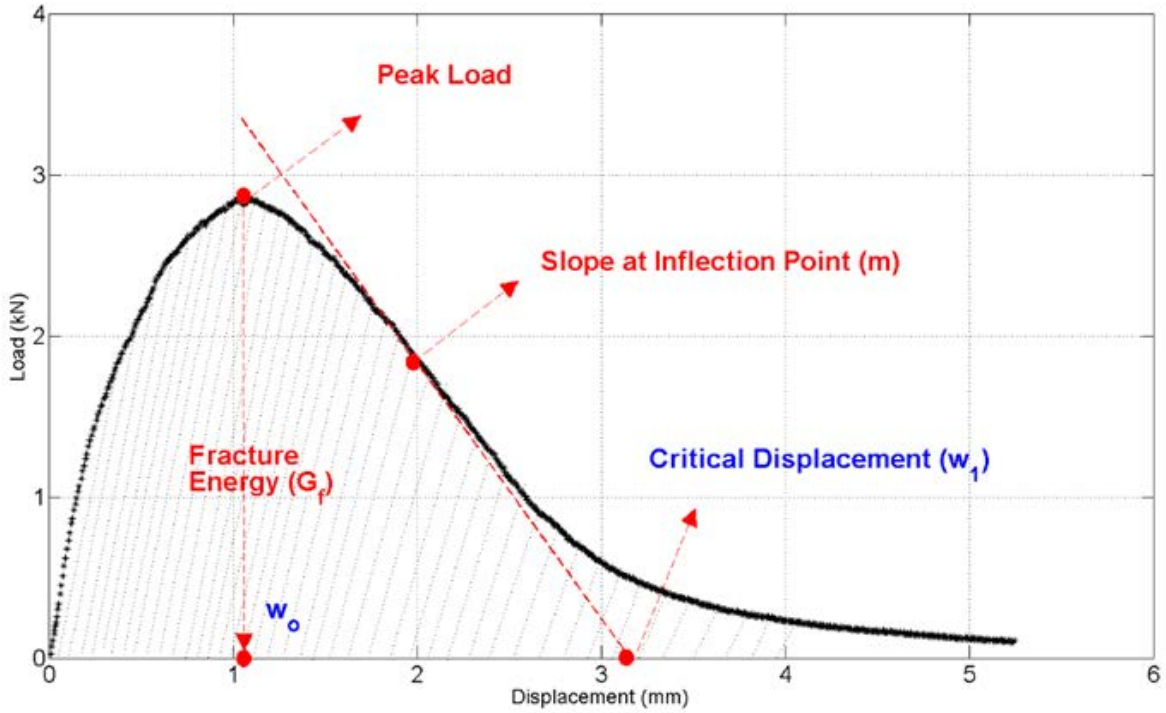


- A comparison of low temperature and intermediate temperature (25ºC) SCB test results indicate the suitability test to discriminate mixes
- 25 ºC and 50 mm/min loading rate were selected

SCB Fracture Results

- Flexibility Index calculated for two lab design (N90) mixes w/ and w/o ABR (30% ~ 7% RAS):

Flexibility Index (FI) = $A * G_F$ /m



SCB Fracture Results

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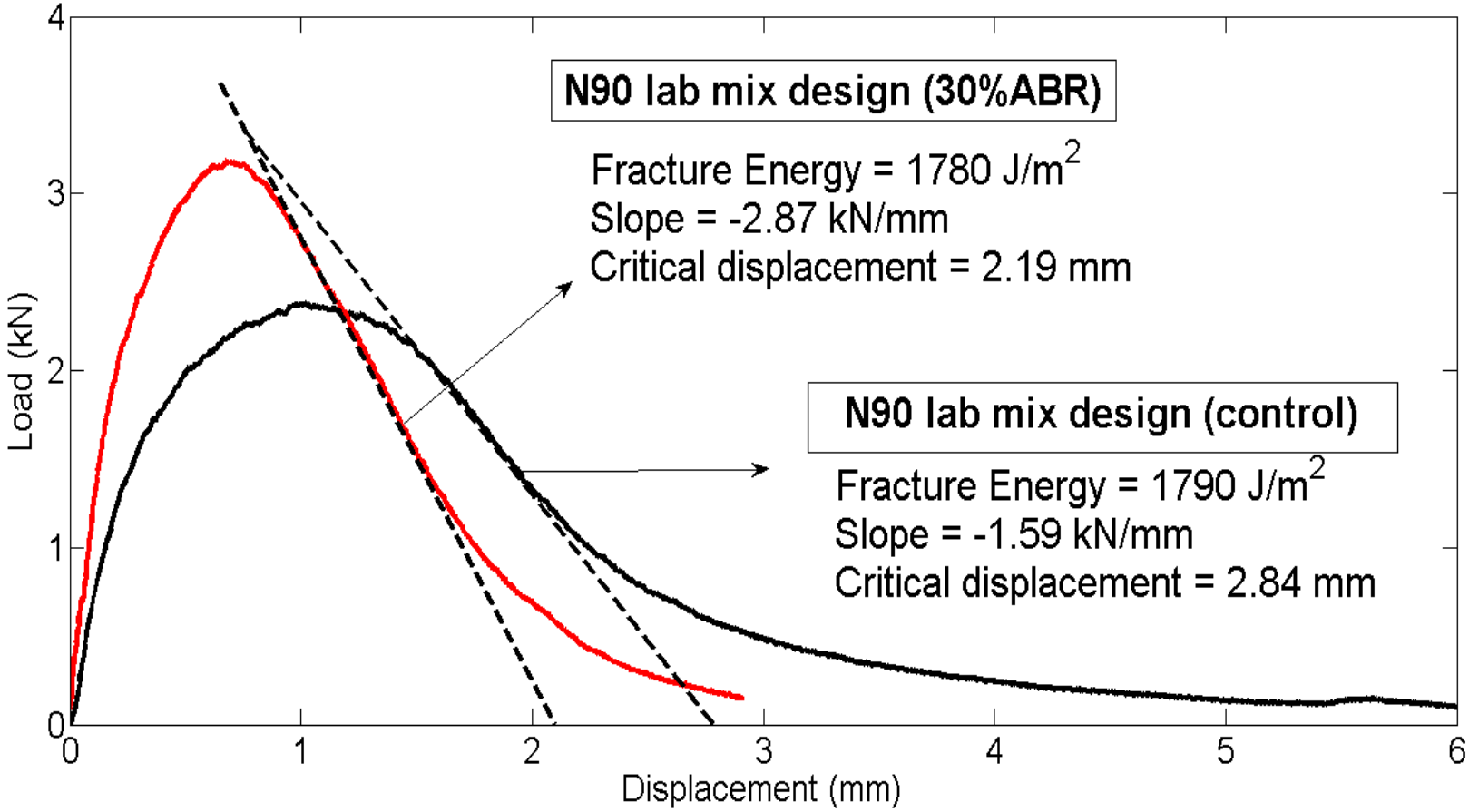
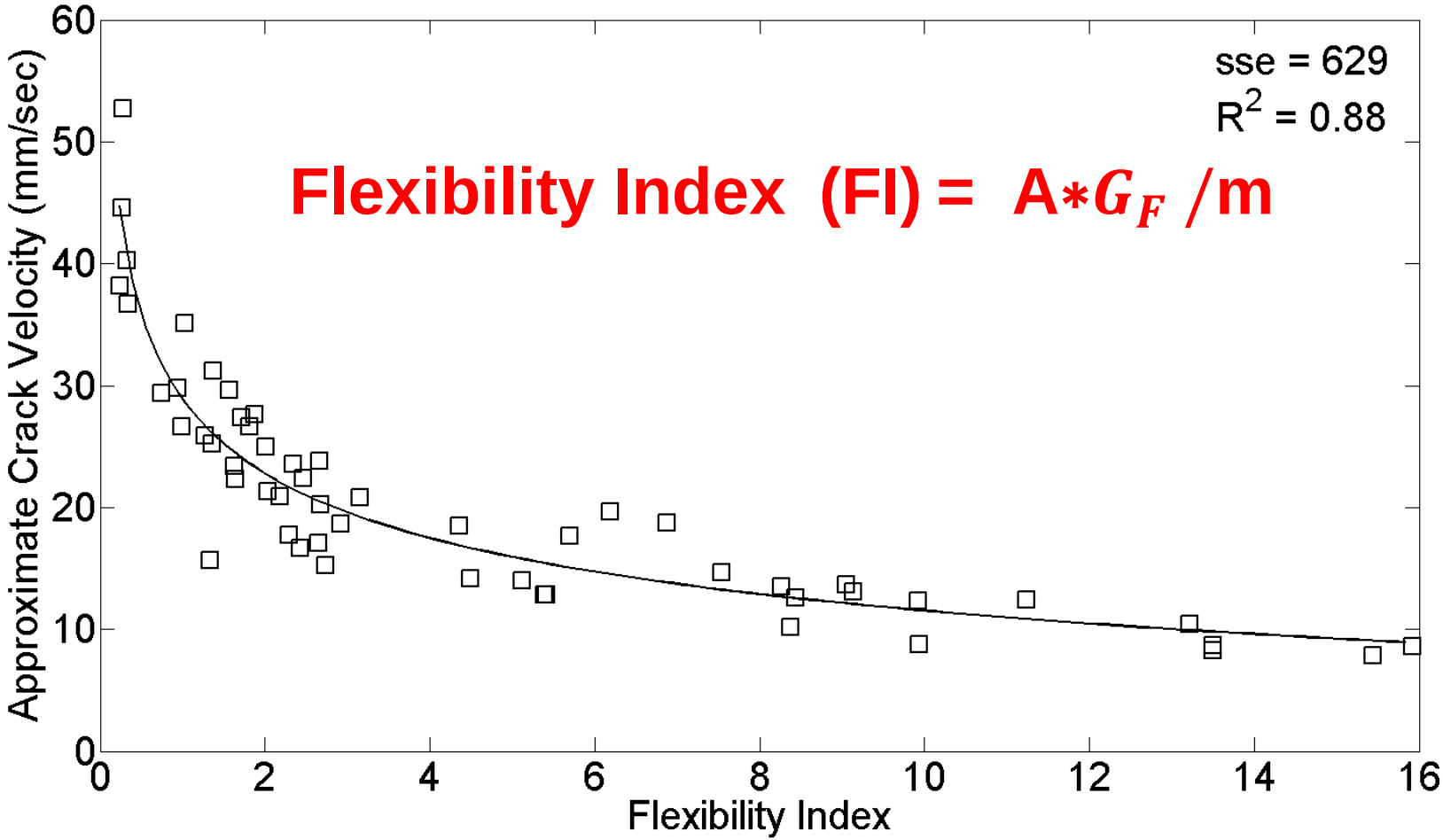


Development of Flexibility Index

- A **theoretically**-supported flexibility index (FI)



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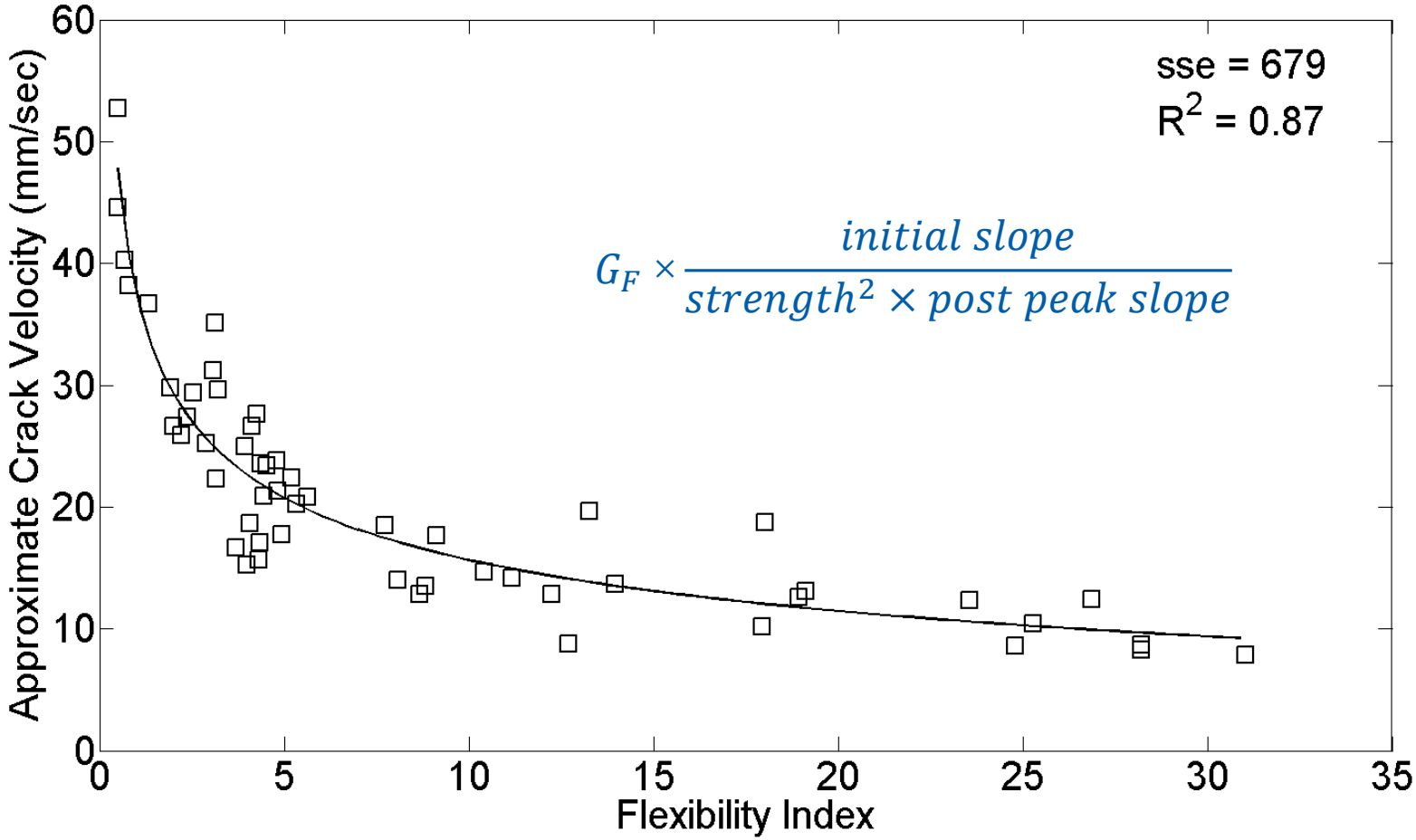

Development of Flexibility Index

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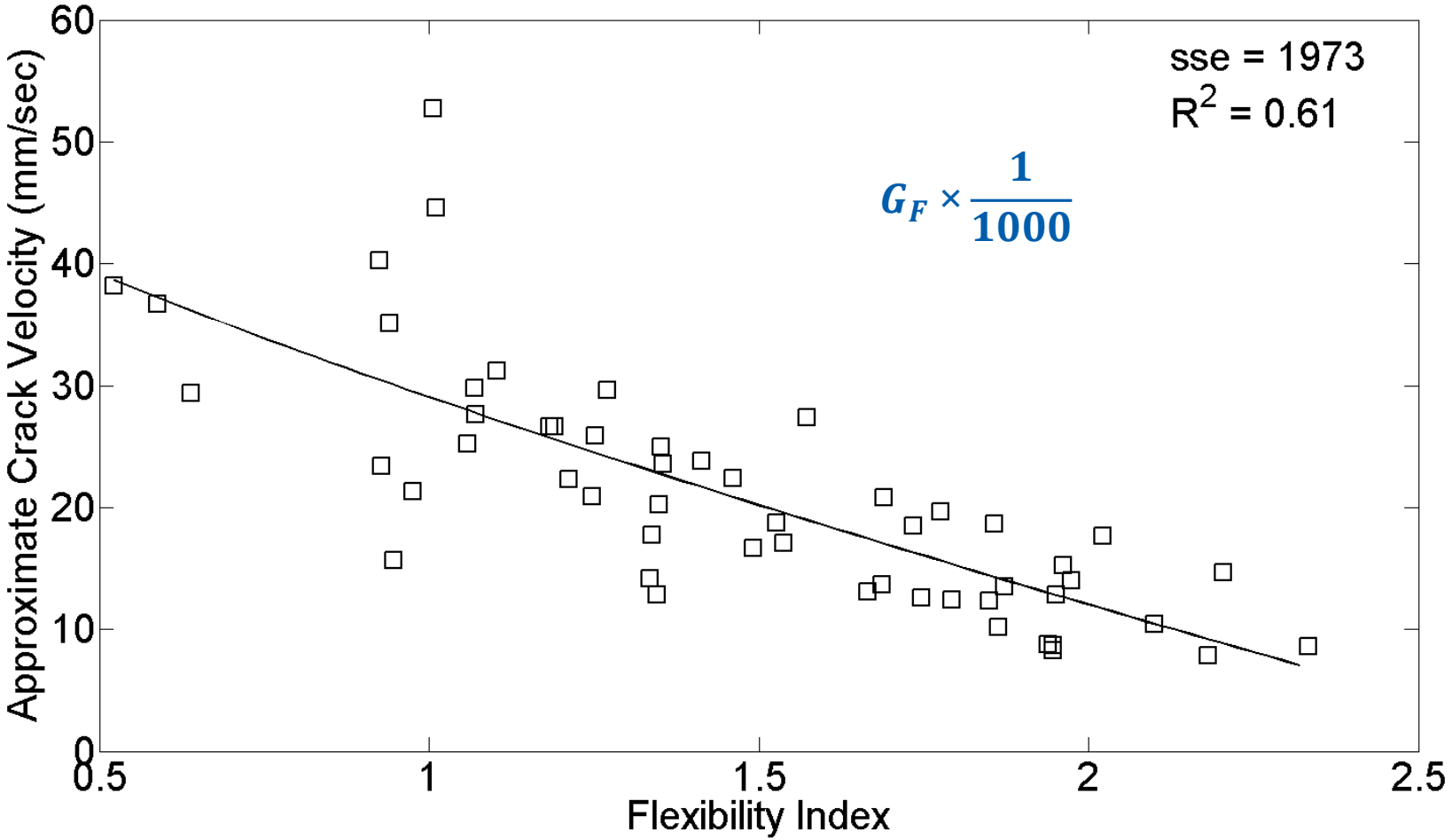
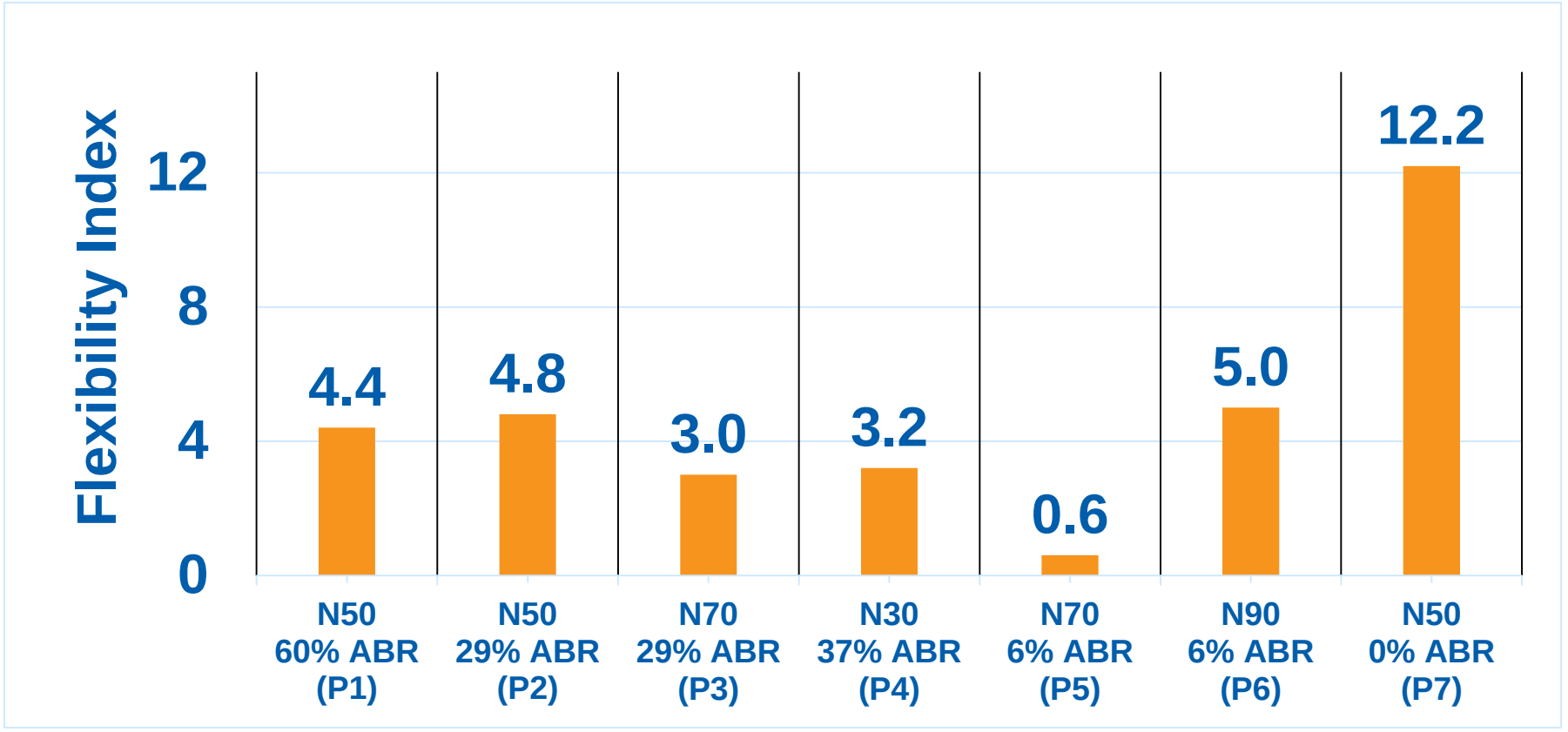
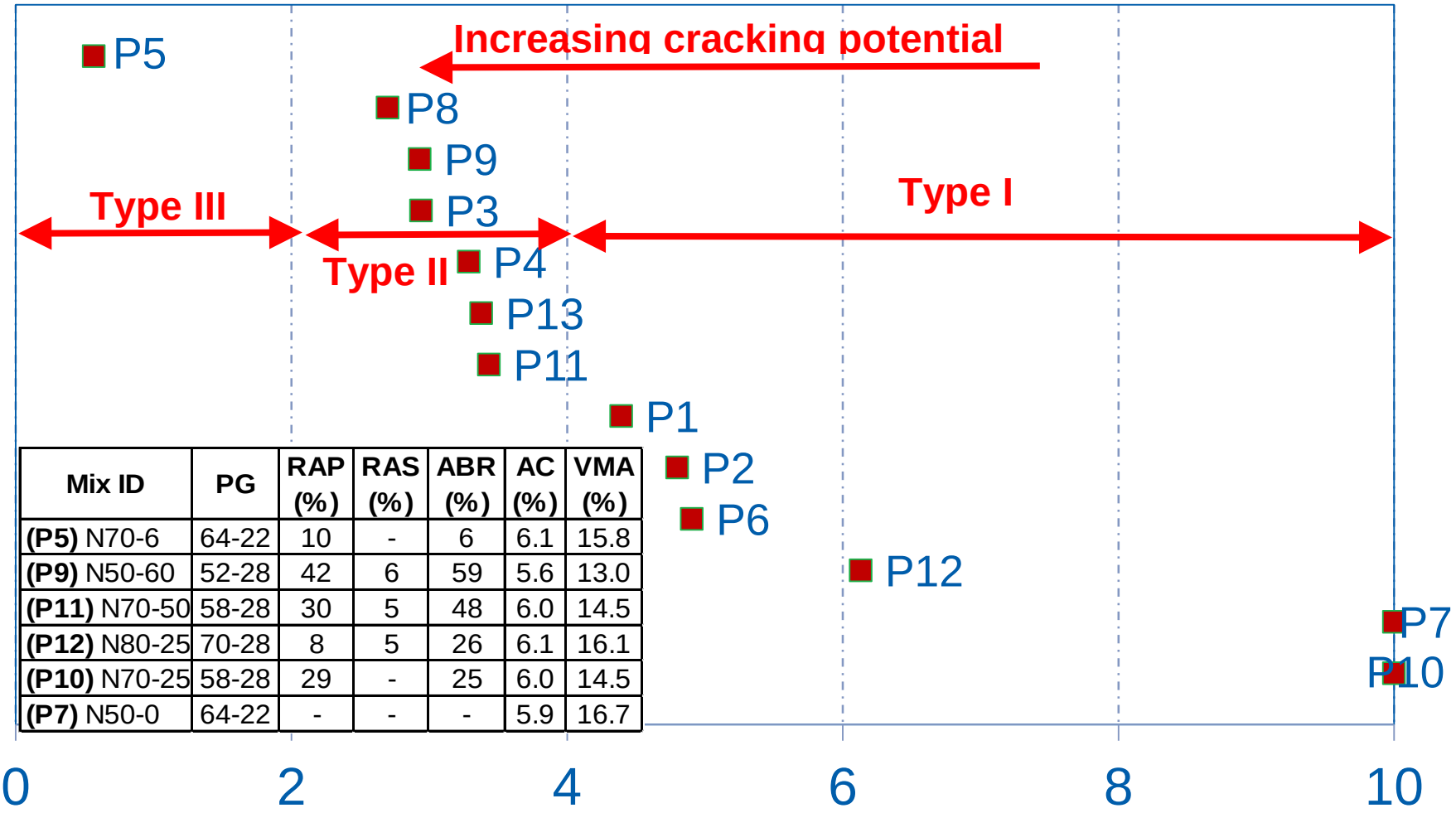


FI Results

- Flexibility index calculated for selected plant mixes

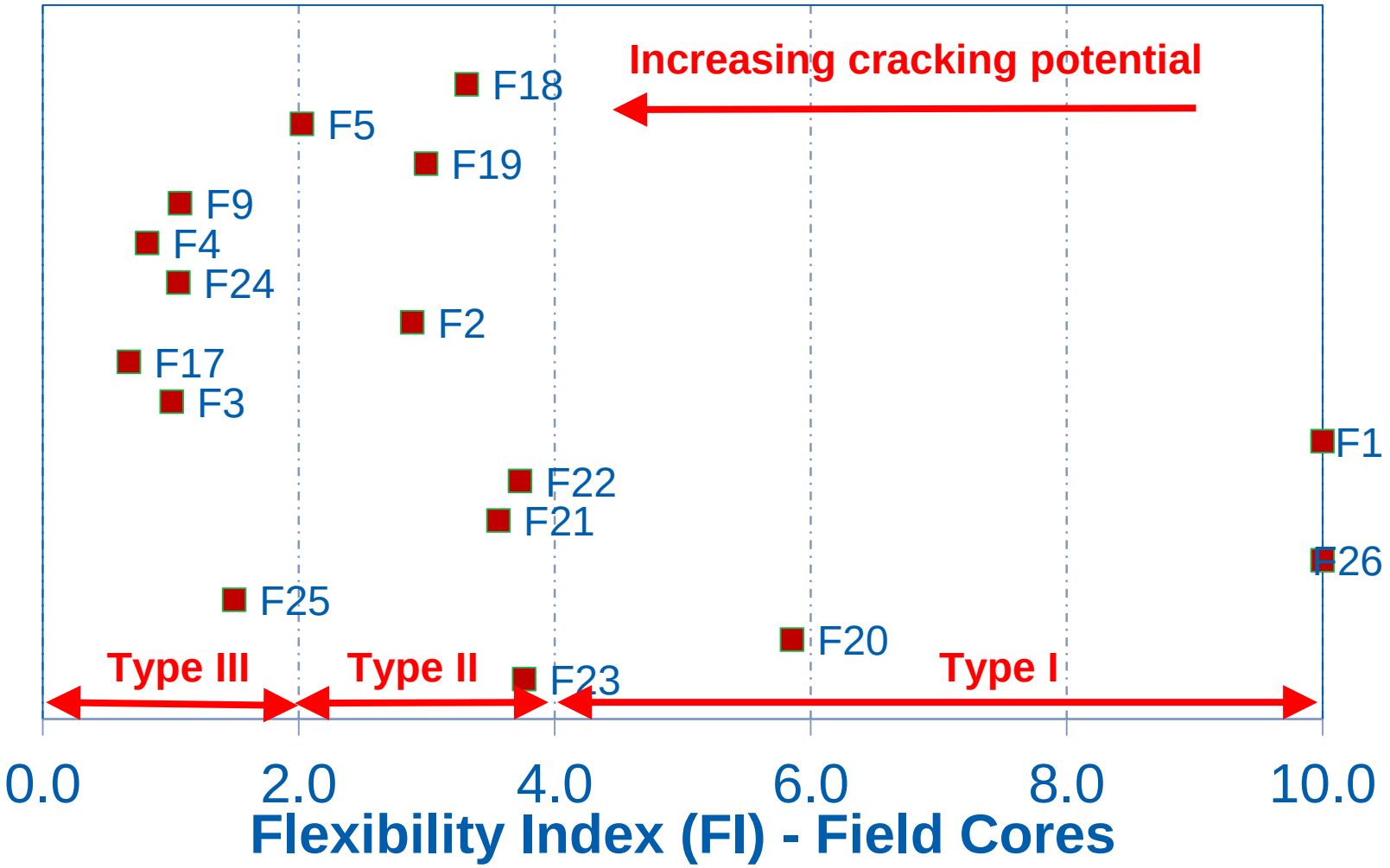


FI - Plant Mixes



Mix ID	PG	RAP (%)	RAS (%)	ABR (%)	AC (%)	VMA (%)
(P5) N70-6	64-22	10	-	6	6.1	15.8
(P9) N50-60	52-28	42	6	59	5.6	13.0
(P11) N70-50	58-28	30	5	48	6.0	14.5
(P12) N80-25	70-28	8	5	26	6.1	16.1
(P10) N70-25	58-28	29	-	25	6.0	14.5
(P7) N50-0	64-22	-	-	-	5.9	16.7

FI (with SF): Field Cores



FI Categorization & Implementation

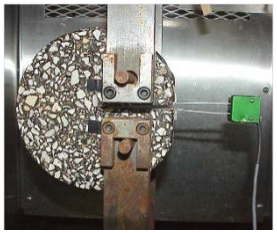
- **Draft Categorization of Mixes Using Flexibility Index and Threshold**

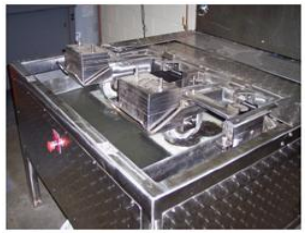
Mix Category	Mix Type Based on Flexibility Index (FI)	Potential Actions and Remedies
Unacceptable Mix	Type III (<2.0)	Reject mix due to high early cracking potential. Redesign the mix.
Inferior Mix	Type II (≤2.0-4.0)	Mix susceptible to cracking. Use the mix only in temporary application or redesign.
Acceptable Mix	Type I (≤4.0-10.0[1])	Accept the mix. Mix is expected to perform adequately. Use the mix in surface overlay or typical pavement applications.

***Lab-compacted mix having FI > 10 is considered high performance mix.**




Low Temperature + Fatigue Cracking

Low Temperature Cracking

Fatigue Cracking/ Service Temperature

Permanent Deformation

-40°C **-20°C** **20°C** **40°C**

Low in-service temperatures

Intermediate in-service temperatures

High Temperatures

Final Remarks

- We need to engineer our asphalt concrete mixes
- Wheel Track, Tensile, and SCB
  - A simple, reliable, and scientifically sound test is introduced
  - Flexibility Index can discriminate between mixes
  - More Validation is underway

Acknowledgment

- IDOT
- FHWA
- ICT Engineers: Aaron Coenen, Greg Renshaw, and Jim Meister
- ICT Students and Staff

THANK YOU

Main Quad – University of Illinois at Urbana-Champaign