From Theory to Practice

Back to Basics in Understanding Asphalt Mix Testing Fundamentals

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ASPHALT MIXTURE

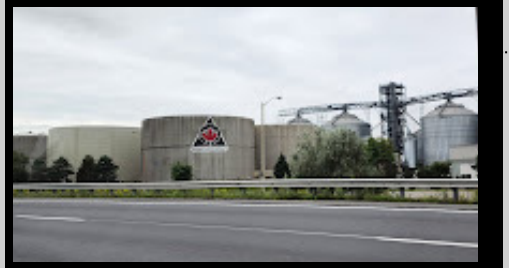
Mixture of aggregate and binder agent

Provide a **hard-top**, while being **waterproof** to a level to prevent the support layers from becoming saturated and loosing support

Stiffness and Behaviour at different in-service temperatures controlled by aggregate skeleton and/or binder properties.

ASPHALT MIXTURE

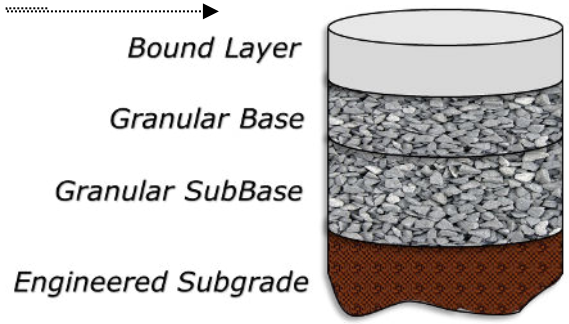
Desired Mix Design = Optimized **Ratio of Aggregate to Binder** Based on **Cost Durability**



%BW= 4 to 6%
$/MT = 40 to 55%

%BW= 94 to 96%
$/MT = 5 to 50%

PRODUCTION



ENERGY
$/MT = 10 to 20%

RECYCLED ASPHALT PAVEMENT (RAP) (Aggregate/Binder)

ASPHALT MIXTURE

Mix Design Historical Trends

Barber Asphalt Paving Company
Mix of AC with Sand and Pulverized carbonite Lime

Hubbard-Field Method
Sand asphalt design
30 blow, 6" diameter with compression test

Bruce Marshall (Mississippi DOT)
Refined Hubbard Field Method – standardization of compaction energy with drop hammer
Used only air voids (3 to 5%)
VFA and VMA added in 1962
Stability and flow utilized

1890 → 1905 → 1920s → 1927 → 1943 → 1993 → NOW?

Clifford Richardson, New York Testing Company
Surface Sand Mix
Asphalt mix for lower layers
VMA terminology used

Francis Hveem (Caltrans)
Surface Area factors to determine binder content (Hveem stabilometer and cohesionmeter)

Air voids not used initially, mixes generally drier relative to others

Issues with fatigue cracking

Superpave
- Level 1 (volumetric-based approach) using 4% air voids, VFA, VMA, DP
- Introduction of gyratory compactor
- Level 2 (performance-based approach) – **Never implemented**

First trial in Ontario placed in 1996

Timeline prepared by Sina.V after reviewing "History of asphalt mix design in North America" published by Asphalt Magazine, Asphalt Institute Link:
http://asphaltmagazine.com/history-of-asphalt-mix-design-in-north-america-part-1/

ASPHALT BINDER

Historical Trends in Testing Binders in Canada

Penetration Graded (i.e. 85/100)

Stiffness
Characterization
At 25°C

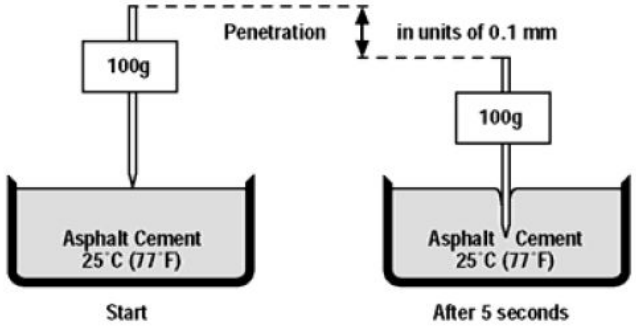
Viscosity Graded (i.e. AC-5)

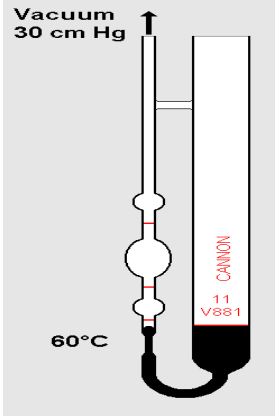
Stiffness & Workability
25°C
135 & 165°C

Performance Graded (i.e. PG 58-28)

Array of testing
Stiffness at Low, Intermediate and High
Workability
Aging susceptibility

1947 → 1970s → Early 1990s → Now?





ASPHALT BINDER

Desired Characteristics
(Stiffness vs. In-Service Temperature)

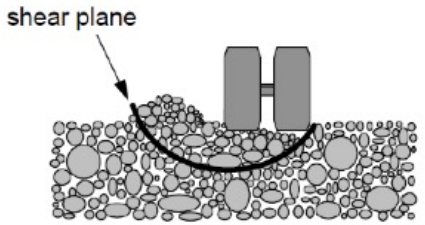
Aging due to Oxidation during production and after being in-service

Thermal Cracking
Non-load Associated

Fatigue Cracking
Load Associated

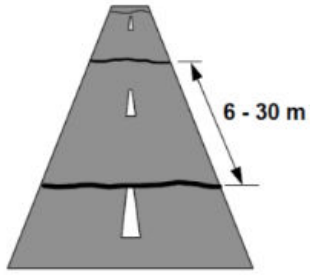
Rutting Shoving
Load Associated

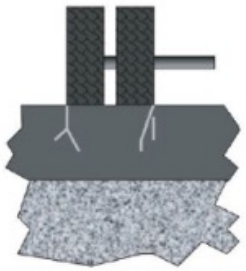
Handling
Production Workability



STIFFNESS

Ideal – Desired





Temperature

Below -16°C

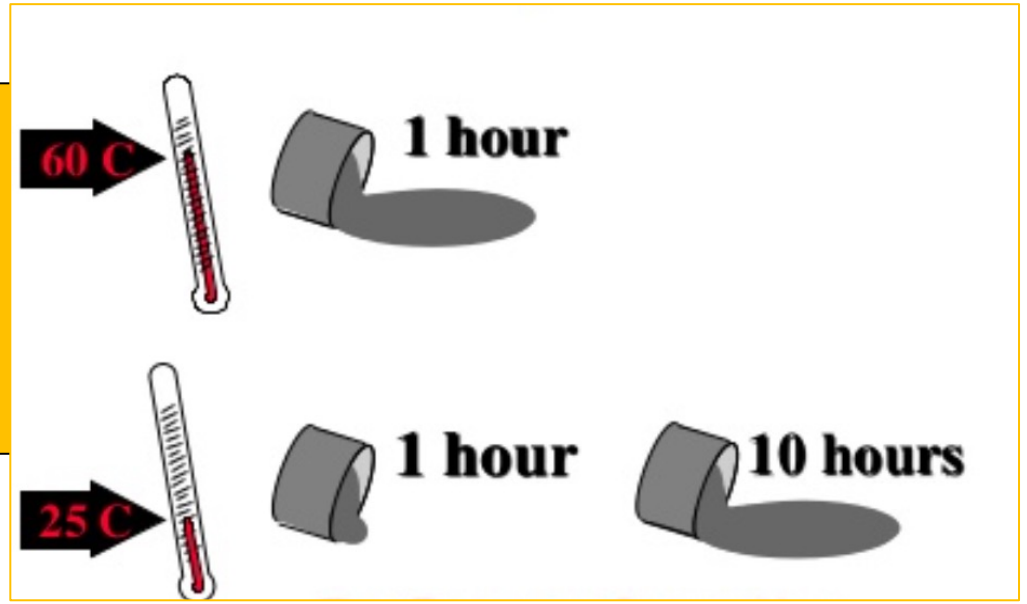
0°C to 25°C

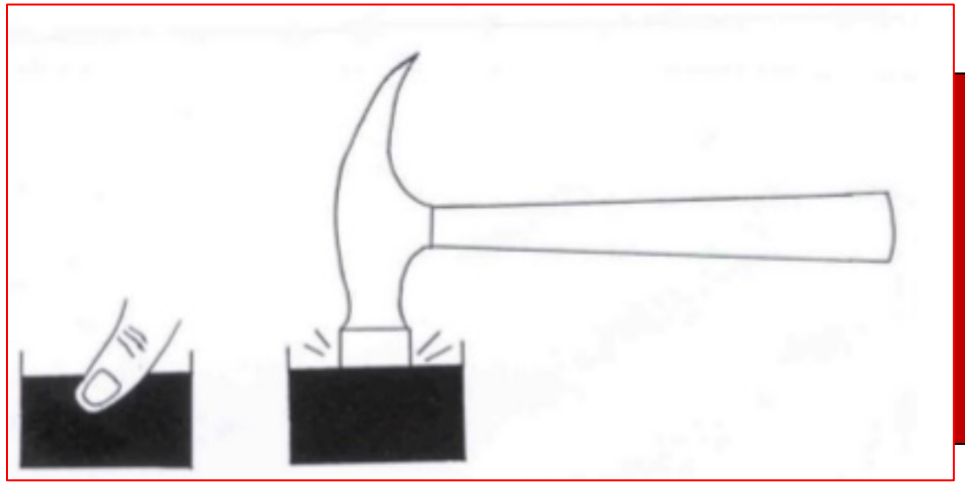
40°C - 60°C

120°C Above

ASPHALT BINDER

Temperature and Time Sensitivity





Rate of Loading

Increasing Loadings

Extreme Events
Structural Resiliency

Changes in crude and refining practices
Changes in other raw material supply

RESILIENCY AND SUSTAINABILITY

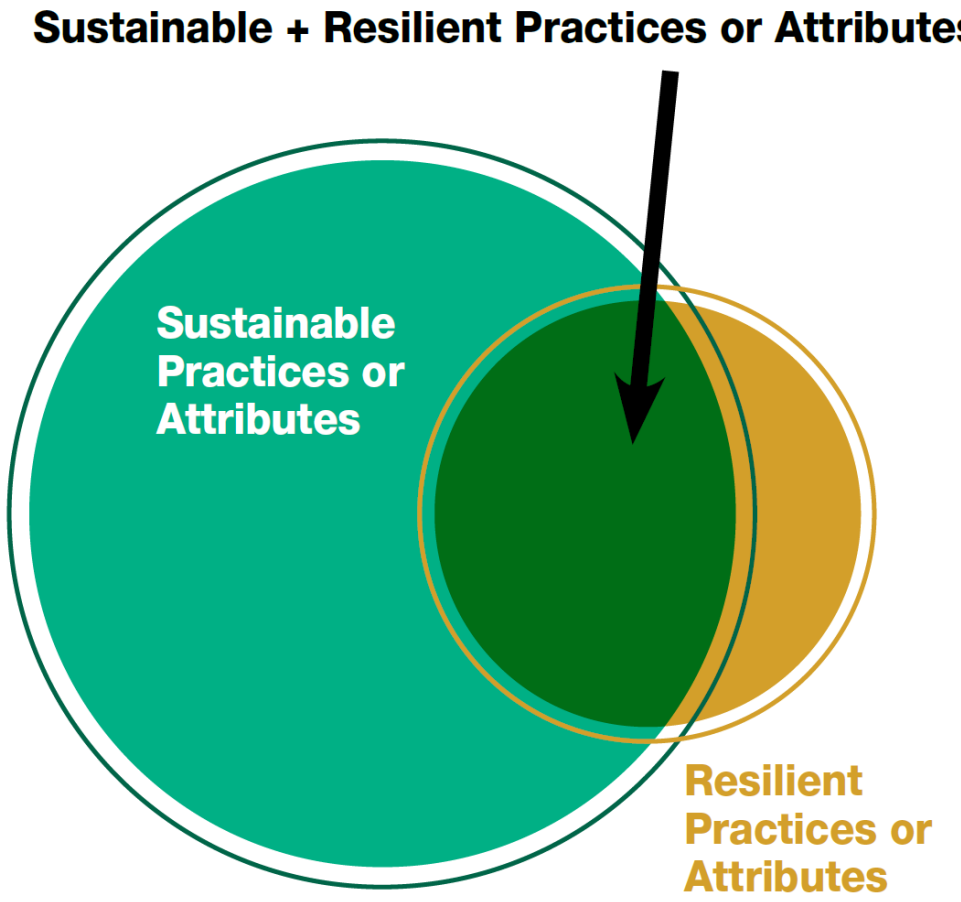


Figure 1. Venn Diagram of Sustainable, Resilient, and Resilient + Sustainable Practices and Attributes for Asphalt Pavements

RESILIENCY AND SUSTAINABILITY

Sustainable + Resilient Practices or Attributes

- Warm Mix Asphalt (low emissions + increase in haul distance)
- Porous pavement systems (stormwater management + nuisance flooding)
- Perpetual Pavement Design
- Deep reconstruction of pavement (increase deep layer moduli)
- Rapid construction
- Ability to adjust pavement design to climate / climatic events to extend pavement life

Sustainable Practices or Attributes

- Use of recycled materials
- Cold Recycled Asphalt
- Asphalt mix and plant optimization

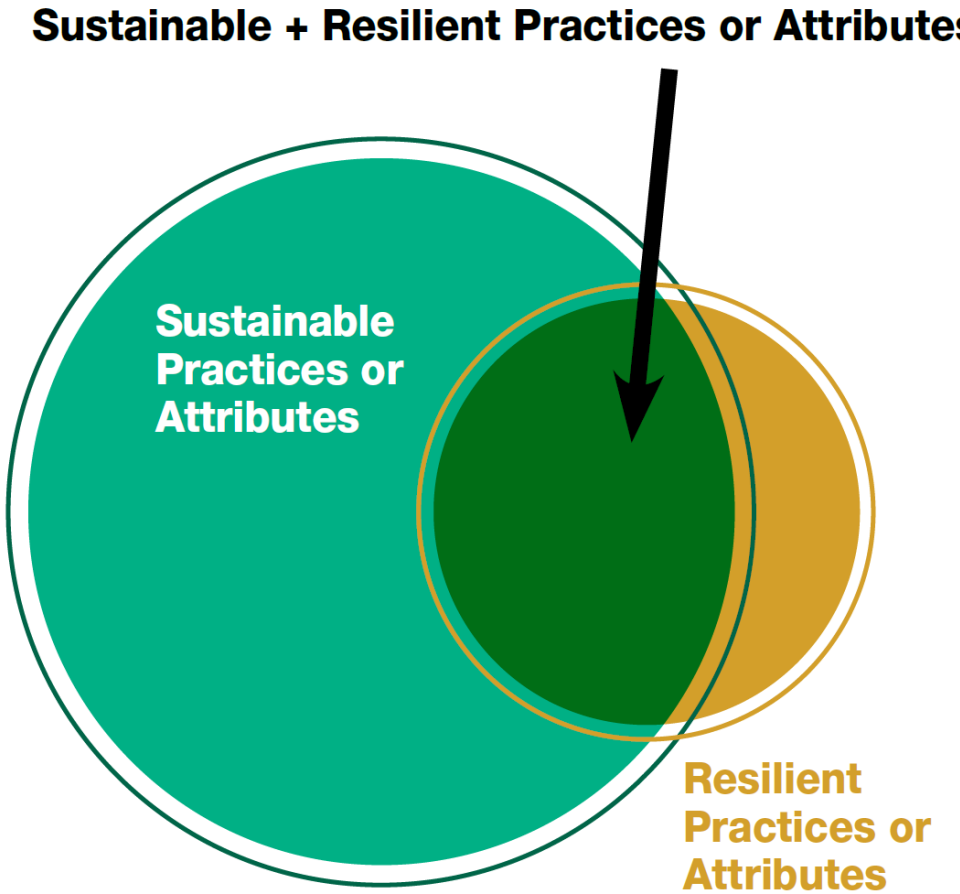


Figure 1. Venn Diagram of Sustainable, Resilient, and Resilient + Sustainable Practices and Attributes for Asphalt Pavements

Resilient Practices or Attributes That Are Not Sustainable

- Use of novel materials with unknown environmental or safety risks
- Use of climate adaptable materials when the social and environmental benefits do not outweigh the costs (e.g., use of polymer modified binders for low volume roads)
- Over-designing for low-risk catastrophic events

Net-zero emissions by 2050

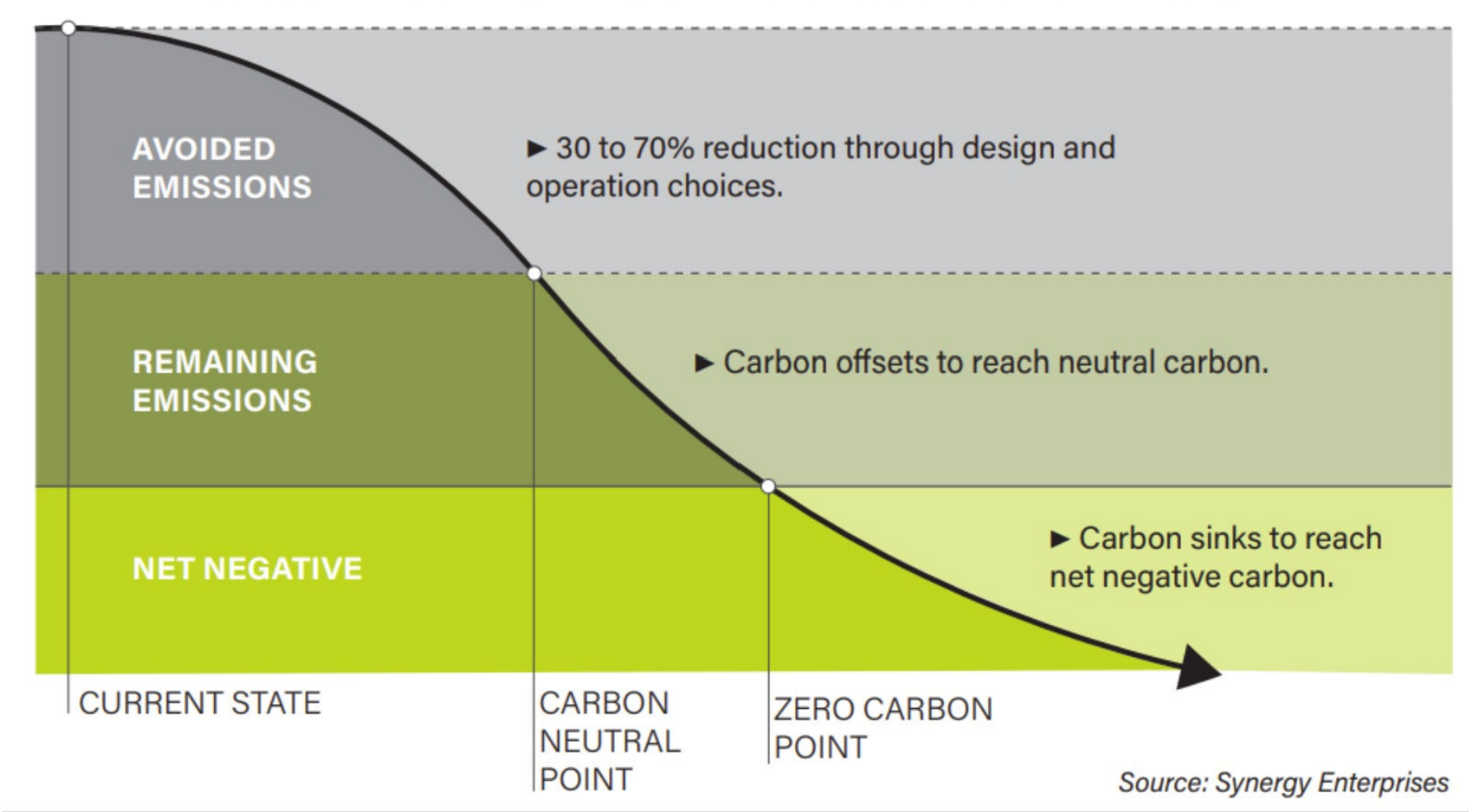
Government of Canada / Gouvernement du Canada

The *Canadian Net-Zero Emissions Accountability Act*

Law to achieve net-zero emissions by 2050
Required reductions at a threshold by 2030

THE DECARBONIZATION PATHWAY

Materials and Processes



Decarbonization Requires EPDs and Product Category Rules (PCRs)

Environmental Product Declaration

"Nutrition label" for asphalt pavement products

EPD "Nutrition" Label

Your Building Product

Amount per Unit

LCA IMACT MEASURES	TOTAL
Primary Energy (MJ)	12.4
Global Warming Potential (kg CO^2 eq)	0.96
Ozone Depletion (kg CFC- 11 eq)	1.80E-08
Acidification Potential (mol H^+ eq)	0.93
Eutrophication Potential (kg N^- eq)	6.43E-04
Photo-Oxidant Creation Potential (kg O3 eq)	0.121

Your Product's Ingredients: Listed Here

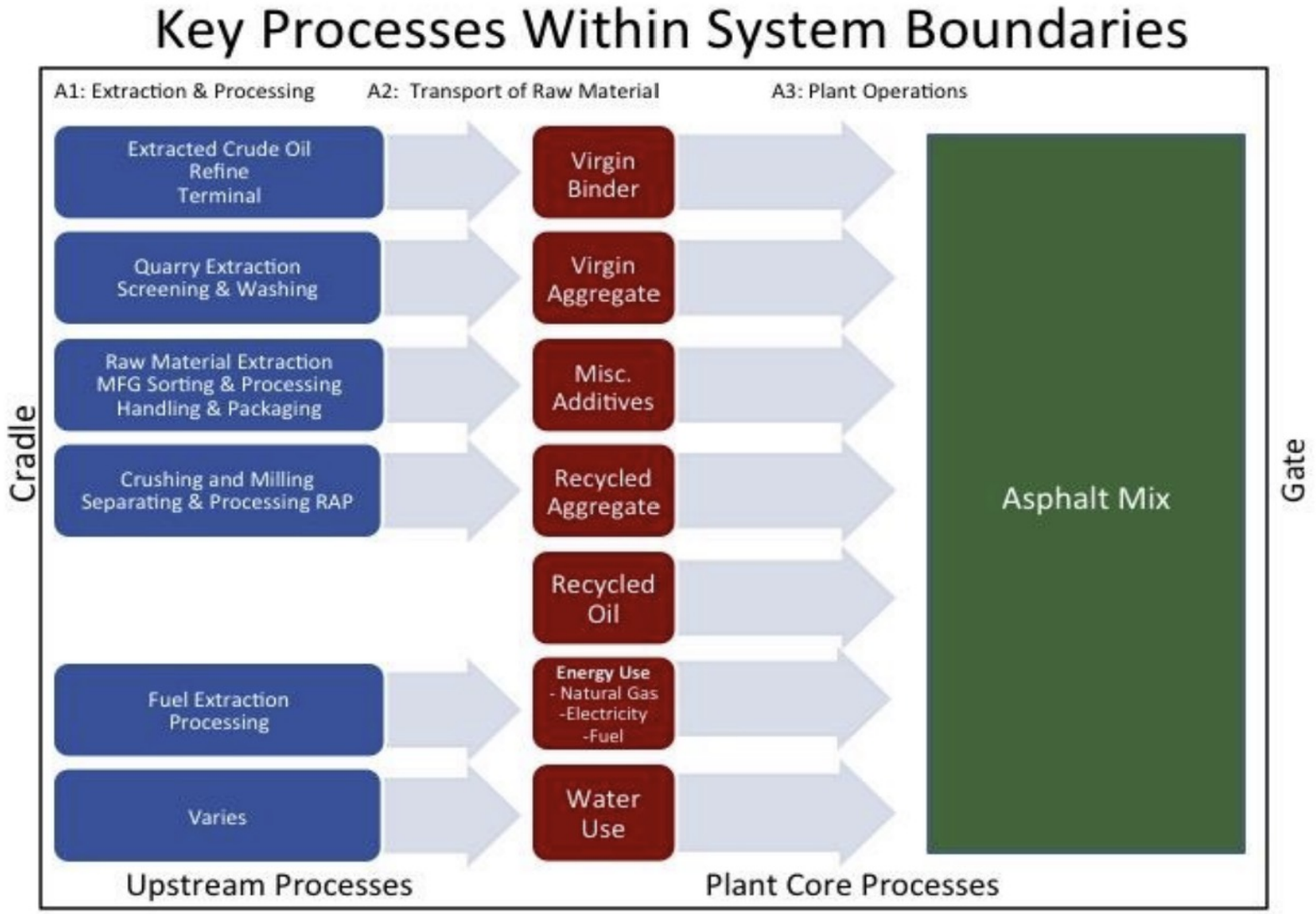
BUT REQUIRES UNDERSTANDING..

Environmental Product Declaration
NAPA VERIFIED

Life Cycle Assessment of Asphalt Mixtures in Support of an Environmental Product Declaration

NAPA
NATIONAL ASPHALT PAVEMENT ASSOCIATION

Emerald
ECO LABEL




Avenue Rd.
Bathurst St. 6 km
Keele St.

CHALLENGES WITH CURRENT DESIGN APPROACH

The Bigger Issue – *"Asphalt Mix Iceberg"*

*Navigating using **PAST EXPERIENCE** by seeing*

- *Asphalt Binder Physical & Chemical Properties*
- *Aggregate Properties*
- AGG-Binder Volumetrics (ABV) Relationship

The "performance tests" don't really reflect performance…

- Marshall Stability, Flow, and Tensile Strength Ratio

Doesn't do a good job at evaluating the benefits (or potential risks) in the incorporation of:

- PG binders
- RAP/Rubberized Asphalt
- WMA additives
- Etc.

Rely on field performance (with many years in service) to "proof" changes/modifications

INCLUSION OF PERFORMANCE TESTING…

Four Approaches

Standard Practice for

Balanced Design of Asphalt Mixtures

AASHTO Designation: PP 105-20[1]

AASHTO

First Published: 2020

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

ASPHALT MIXTURE

Considering Performance in Mixture Design

A **Recipe & Volumetric Selection**

B **Performance-Verified Volumetric Design**

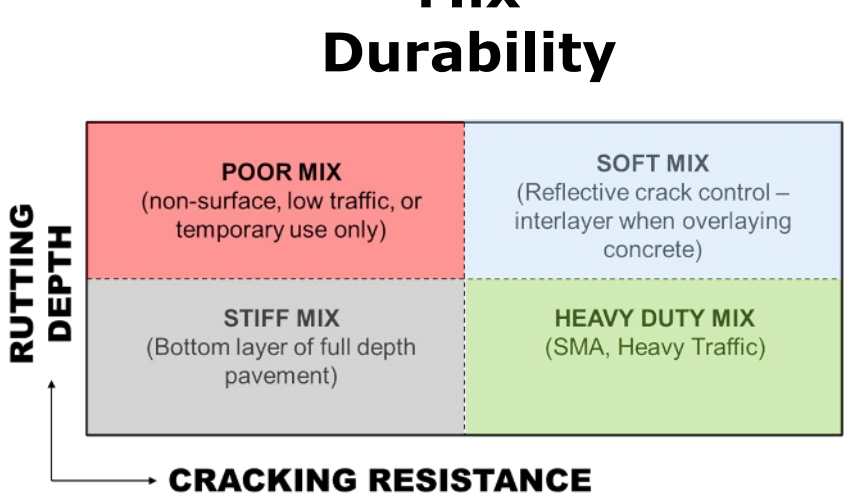
Verification of resistant to a specific distress
Example: Asphalt Cement (AC) modification to resist fatigue cracking

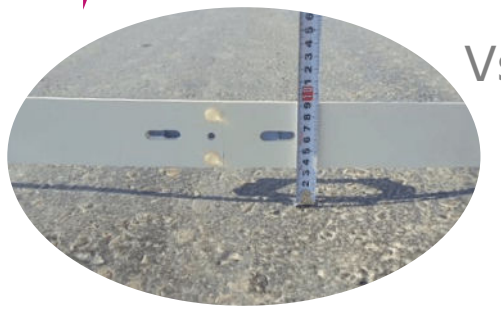
C **Performance-Modified Volumetric Design**

Adjustment of mix proportions to resist a specific distress
Example:

D **Performance-Based Design**

Durability
Performance testing for **Pavement design input**
Conduct volumetric for QA





Vs.

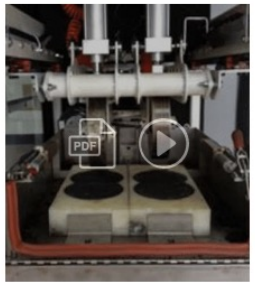
“Balanced mix design”

So where to start?

NAPA
NATIONAL ASPHALT PAVEMENT ASSOCIATION

BALANCED MIX DESIGN RESOURCE GUIDE

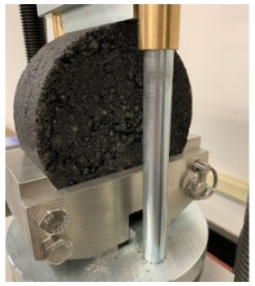
Rutting


ASPHALT PAVEMENT ANALYZER


FLOW NUMBER TEST

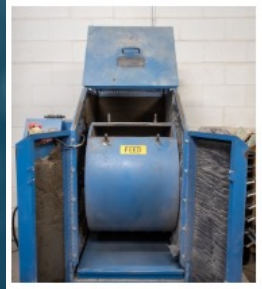

HAMBURG WHEEL-TRACKING TEST

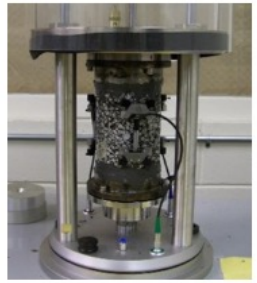

HIGH TEMPERATURE INDIRECT TENSION (HT-IDT)

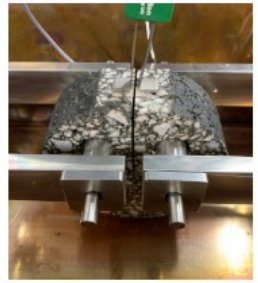

RAPID SHEAR RUTTING TEST (IDEAL-RT)


STRESS SWEEP RUTTING (SSR)

Cracking


CANTABRO TEST


DIRECT TENSION CYCLIC FATIGUE TEST


DISC-SHAPED COMPACT TENSION TEST

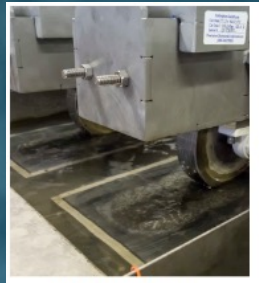

INDIRECT TENSILE ASPHALT CRACKING TEST (IDEAL-CT)


NFLEX FACTOR


OVERLAY TEST

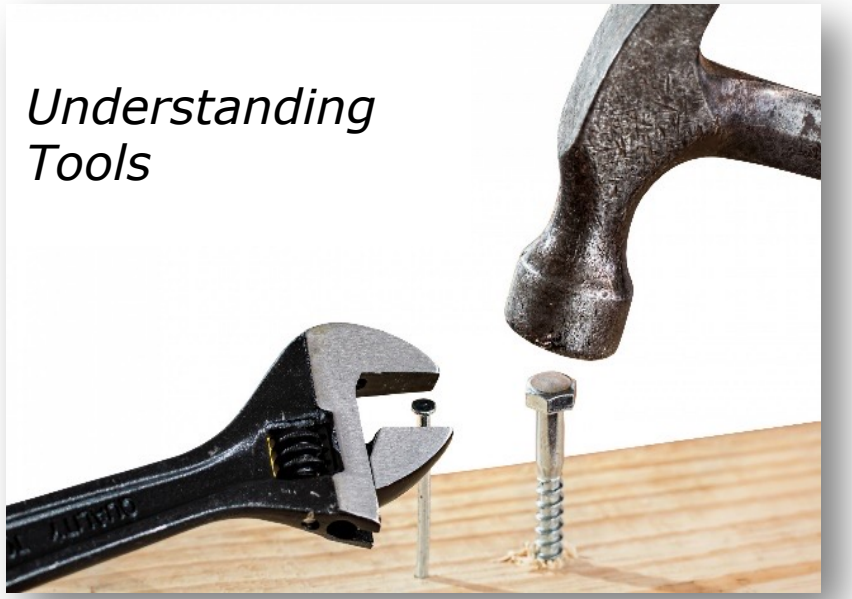

SEMI-CIRCULAR BEND TEST (LOUISIANA METHOD)

Moisture Damage


HAMBURG WHEEL-TRACKING TEST


TENSILE STRENGTH RATIO

NEED FOR EXPERTS IN SELECTING THE RIGHT MIX DESIGN AND TEST



Not designing for a driveway, if runway airfield mix was needed

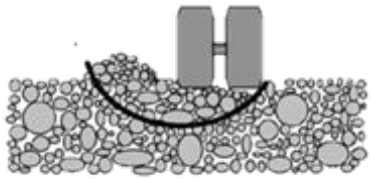
BE PRACTICAL!!
THEORY VS. PRACTICALITY

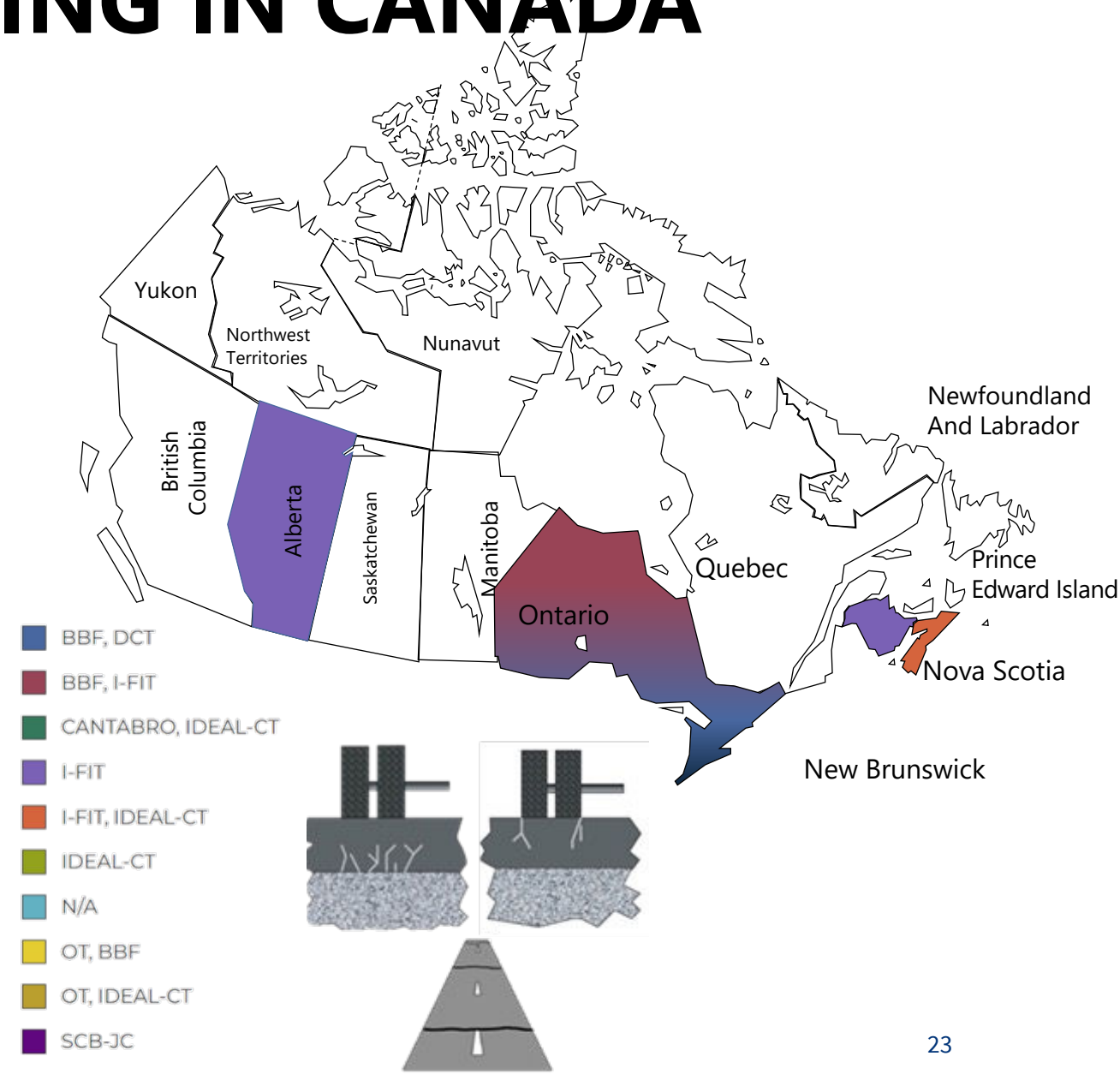
Avoid measuring with a caliper precision,
..mark with piece of chalk
..and cut with

Must be able to see the "total picture"
and not just a part

PERFORMANCE TESTING IN CANADA

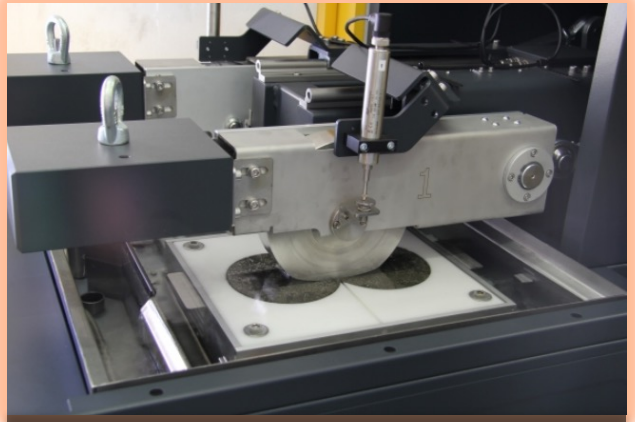
Road Agencies



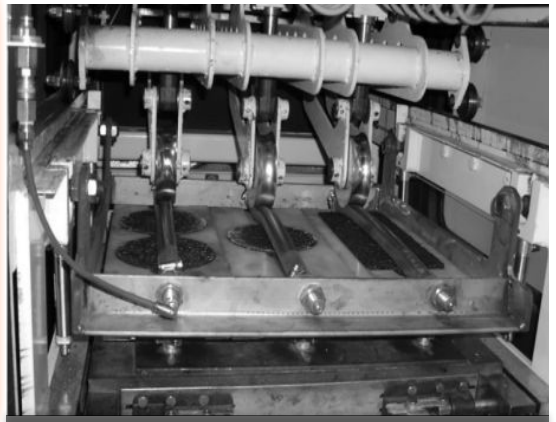


ASPHALT MIXTURE

Test Methods – Permanent Deformation/Rutting

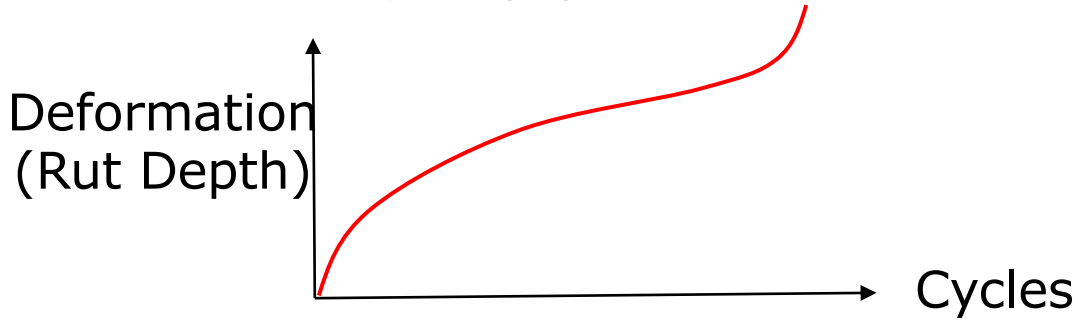


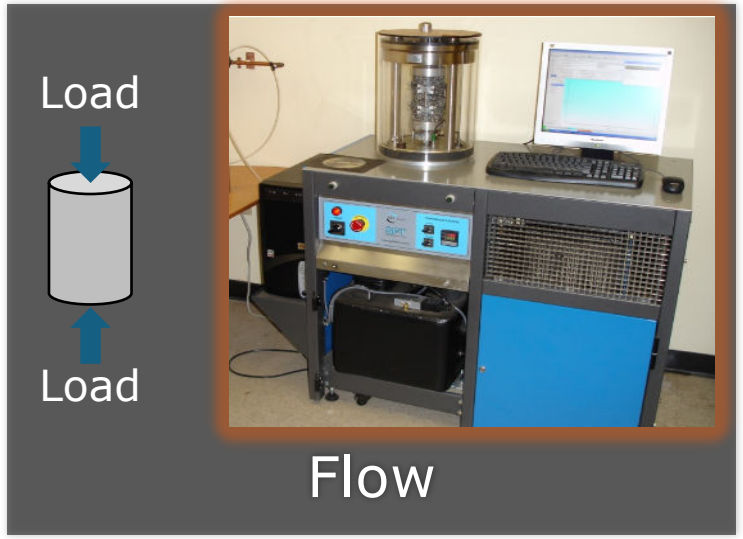
Hamburg Wheel Tracking



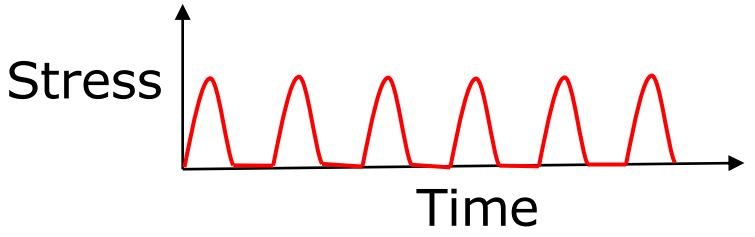
Asphalt Pavement Analyzer

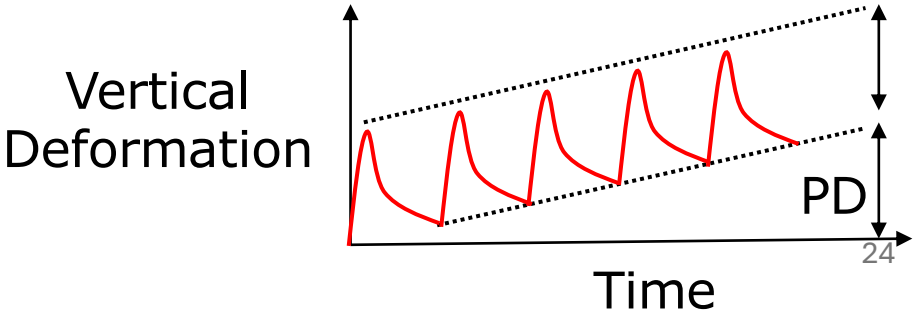
Simulative





Flow





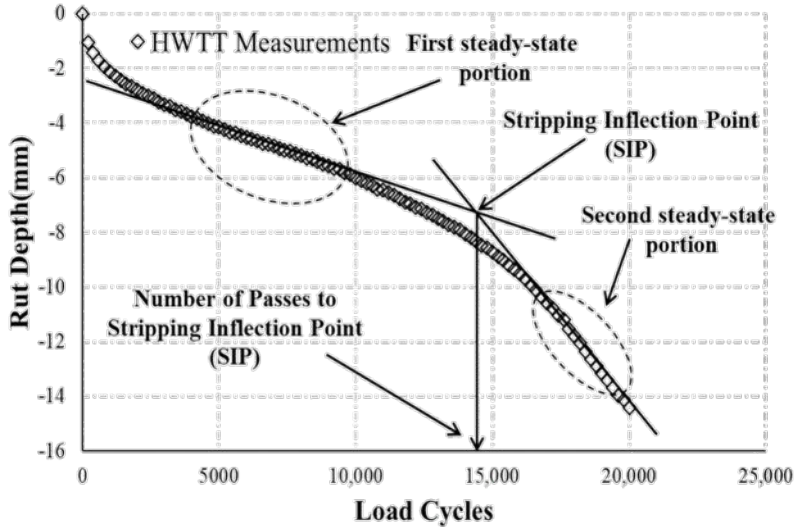
HAMBURG WHEEL TRACK

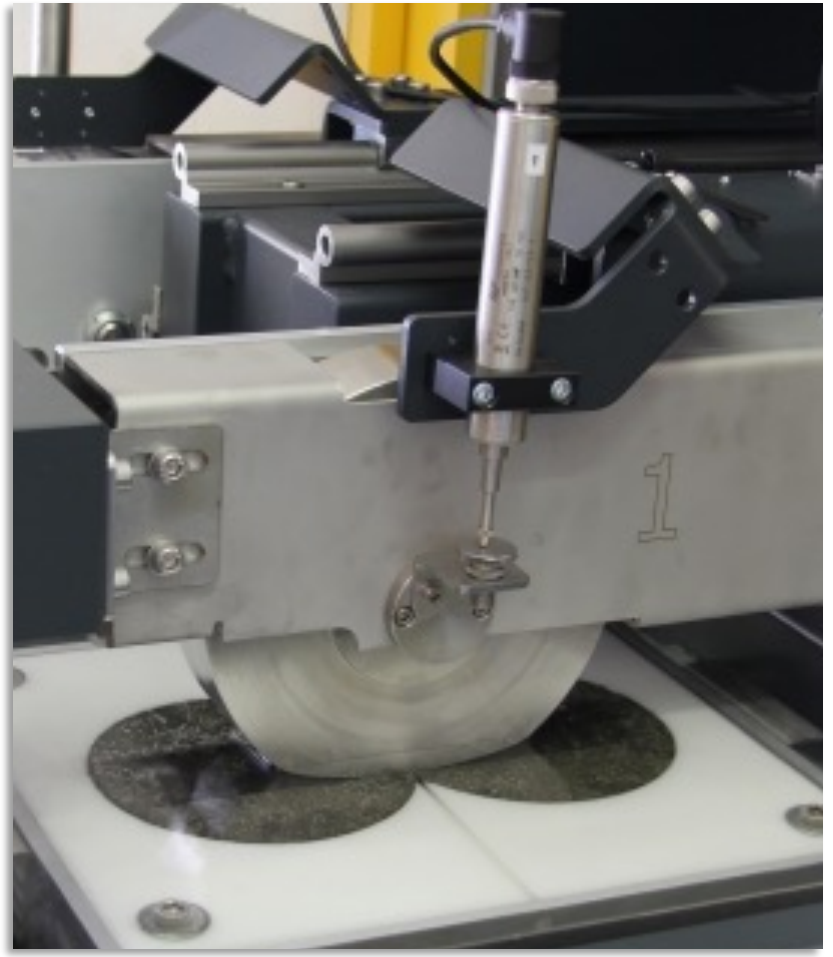
AASHTO T 342

Tracking 705 N of load wheel for 20,000 passes or more

Submerged at varying high temperature

Ranged between 40°C to 50°C [sensitive to Mix properties]





BEFORE ***AFTER***

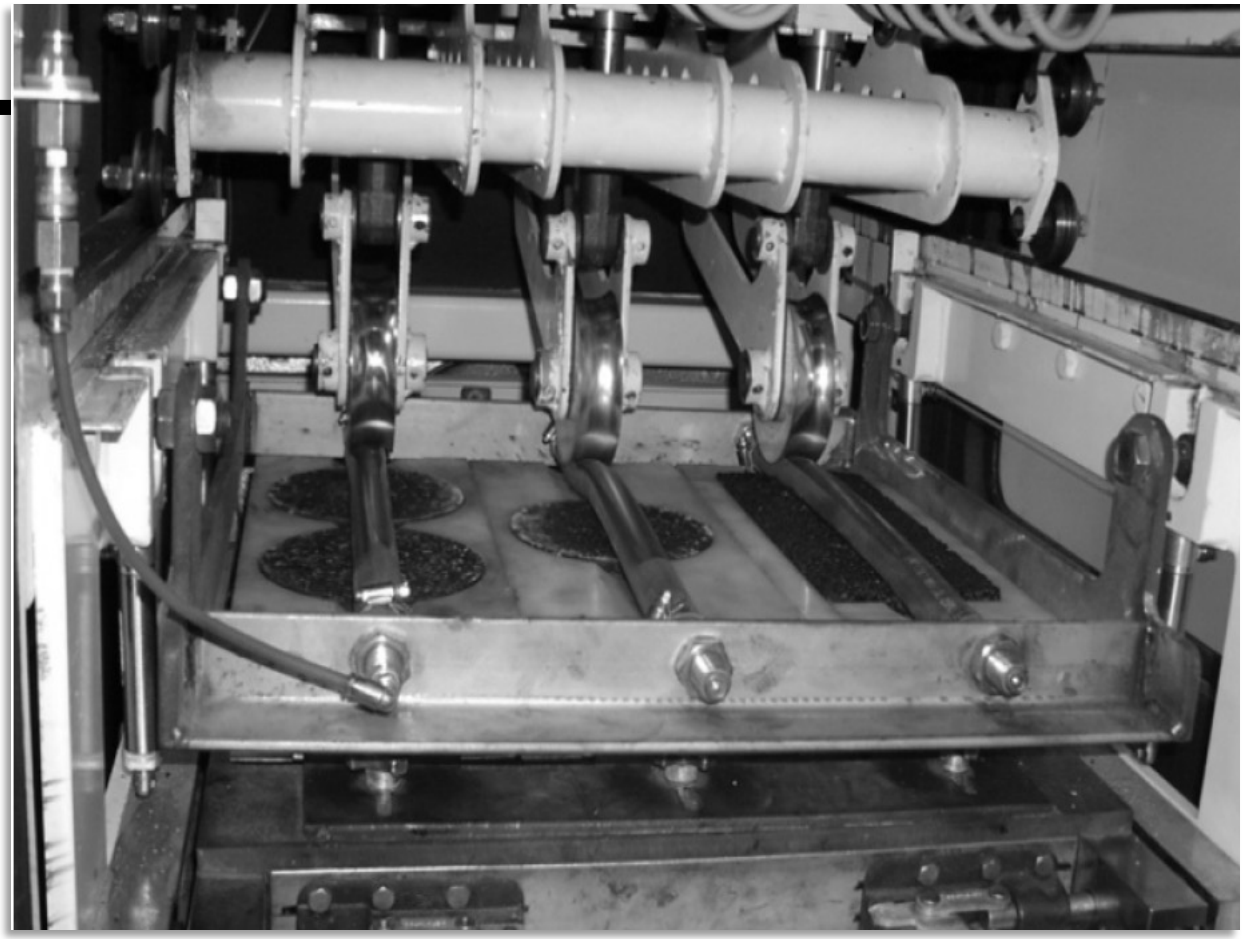
ASPHALT PAVEMENT ANALYZER

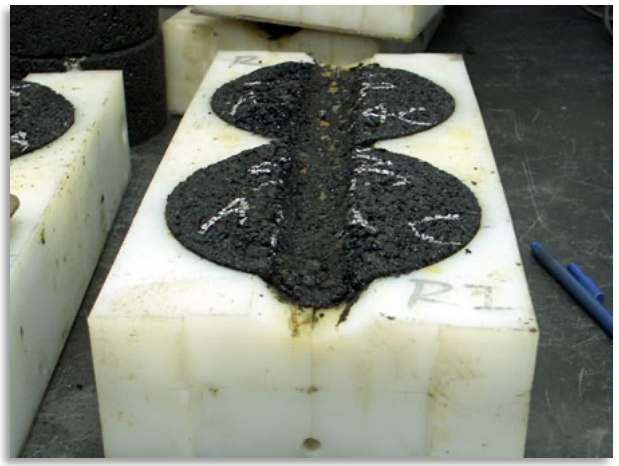
AASHTO T 340

Tracking 578 N of load wheel for 8,000 passes or more

Load applied through pressurized hose (up to 125 psi)

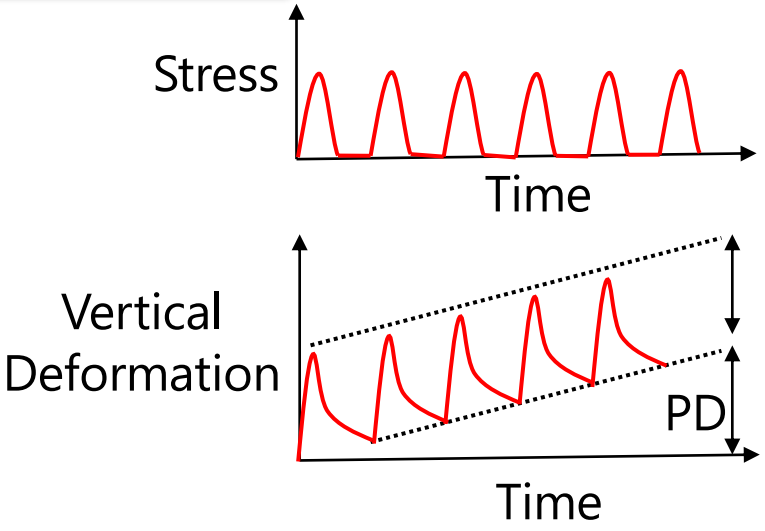
Ranged between 58°C to 70°C (PG-High Temp.)





FLOW NUMBER

0.1s loading
0.9s rest



AASHTO T 378

Cyclic stress

Cored out of Gyratory-sized (H 150 X D 100 mm)

Performed at high temperature (i.e. summer temperatures)

HWY Traffic Level (Million ESALs)	Minimum Flow Number (cycles)	General Rut Resistance
< 3	--	Poor to Fair
3 to < 10	53	Good
10 to < 30	190	Very Good
≥ 30	740	Excellent

NCHRP Report No.673 (Project 9-33) (A Manual for Design of Hot-Mix Asphalt)

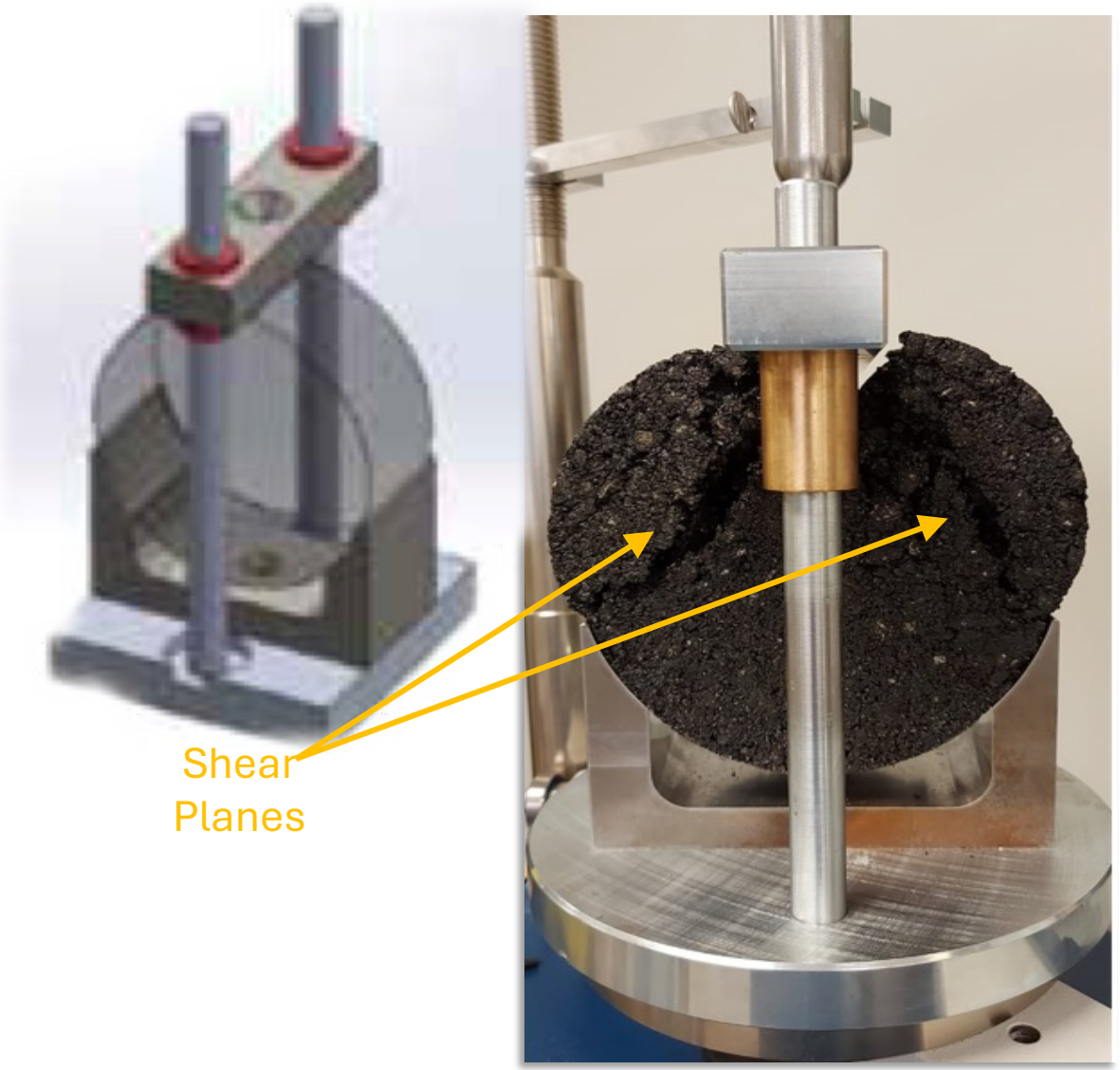
INDIRECT TENSION ASPHALT (IDEAL)
Rapid shear rutting test (RT)
In Development

Drafted ASTM Work Item (WK 71466)

Gyratory-sized (H 60 mm X D 150 mm)

Performed at 40°C or higher

Quality Assurance Friendly



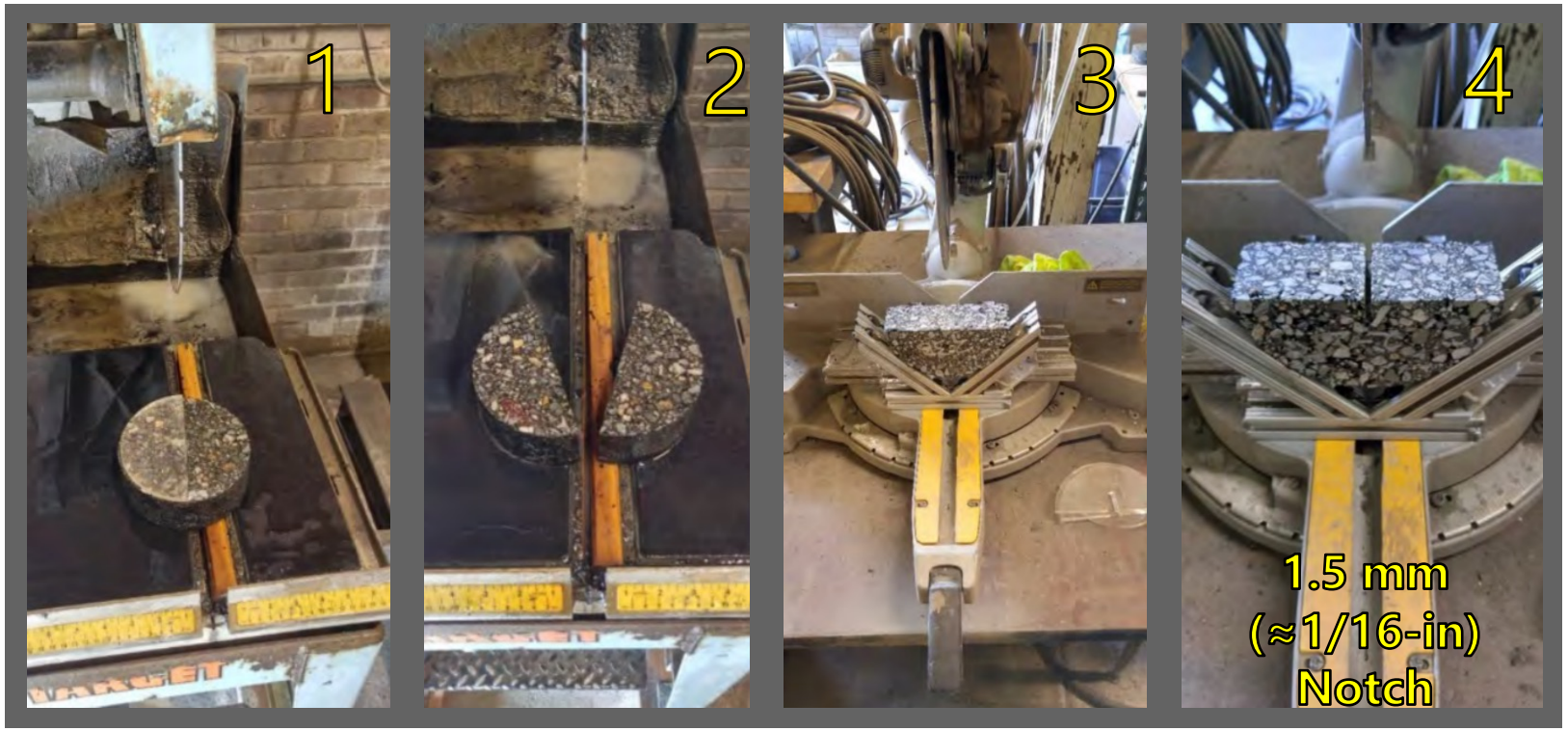
SCB CRACKING RESISTANCE (I-FIT)

Practice Ready

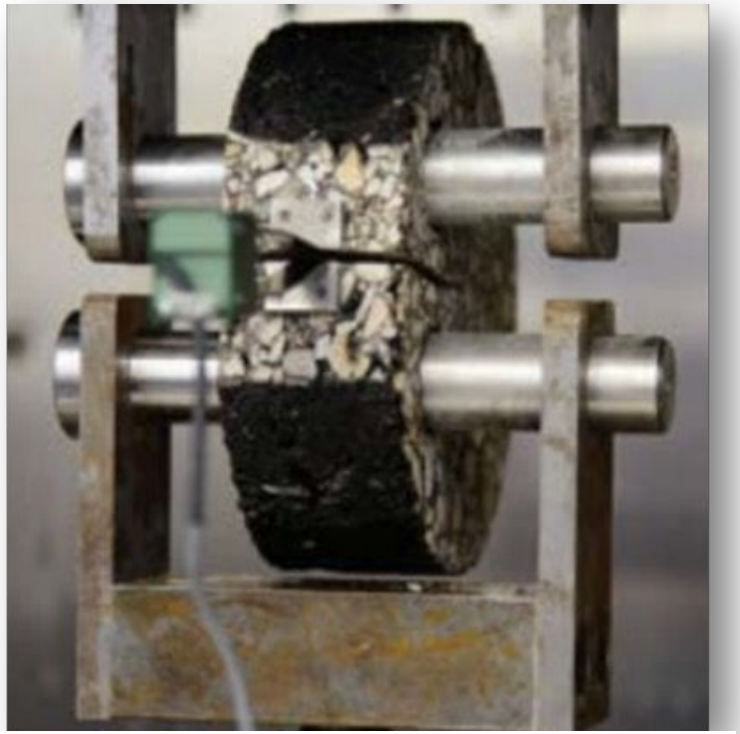
AASHTO T 393

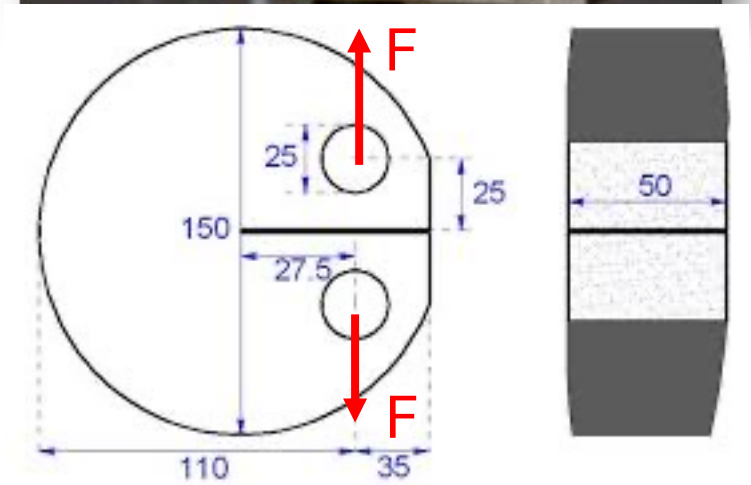
Gyratory-sized (H 50 mm X D 150 mm)

Performed at 25°C or lower



DCT – THERMAL CRACKING



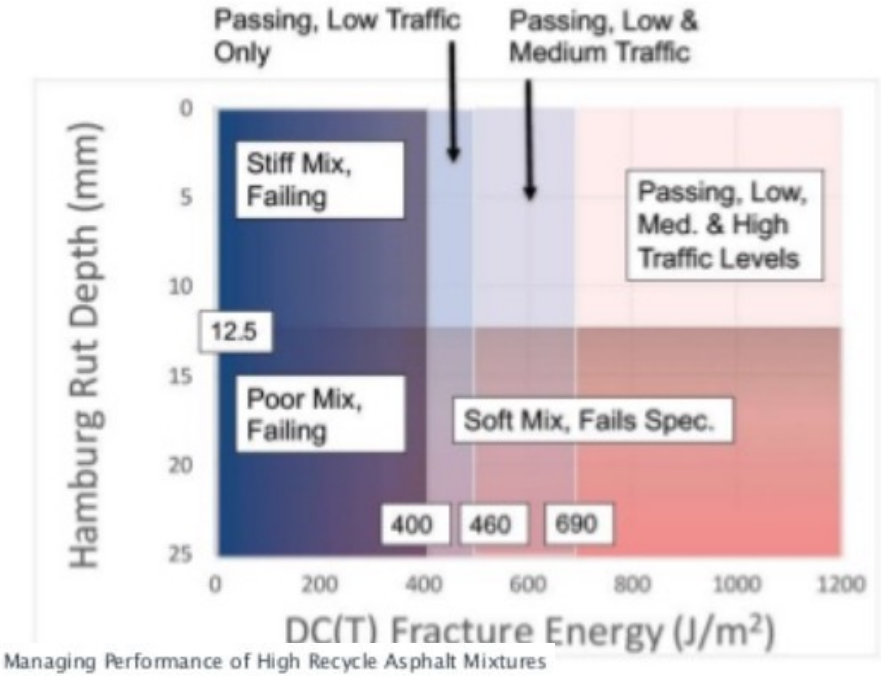


ASTM

Gyratory-sized

Performed at 10°C higher than low PG grade

Captures fracture energy and relaxation of the mix at colder conditions



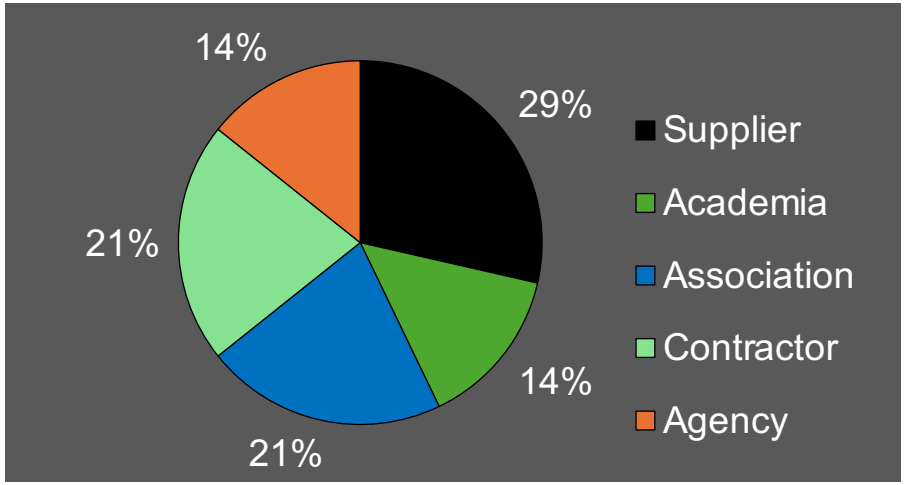
Managing Performance of High Recycle Asphalt Mixtures

Buttlar, et.al, Performance-Space Diagrams for Asphalt Concrete Mixtures, AAPT, 2016


ARE WE READY?

ONTARIO ASPHALT EXPERT TASK GROUP (OAETG)

Open to all industry stakeholders



Chair: Dr. Sina Varamini, Ph.D., P.Eng.,
General Manager, CRM Canada/Adjunct Professor

Vice-Chair: Prabhdeep Lubana, P.Eng.
Principal – PNJ Consulting

Secretary: Dr. Vimy Henderson, Ph.D., P.Eng..

Principal – PTech Engineering Solutions Inc.

Access to Academic Research Groups at the National Level

University of Alberta
Canada NRC-CNRC
University of Waterloo
McMaster University
UNB EST. 1785 University of New Brunswick

Regional User Producer Groups & Associations

OAETG OBJECTIVES

OUR MANDATE

I-ABC

IDENTIFY improvements to binder and mixture specification and testing methods *Ontario-specific climate and traffic conditions*

ACT as an **advisory group**
Recommending and/or perform asphalt research interests and needs

BRAINSTORM asphalt-related and emerging issues
Particularly on subjects of RAC and Mix Performance acceptance

CONTRIBUTE to content development and organization of the Asphalt Technical Symposium (ATS)

UNDERSTANDING THE PERFORMANCE-RELATED MIX TESTS PART OF OAETG's 5 YEAR VISION

BLD

Bridge the **knowledge gap** in "*Performance Testing methods and Acceptance*"

Literature search on **practice-readiness** of "mix performance" & thresholds

Develop industry-wide variability benchmarking program: **Mix Asphalt Program (MAP)**

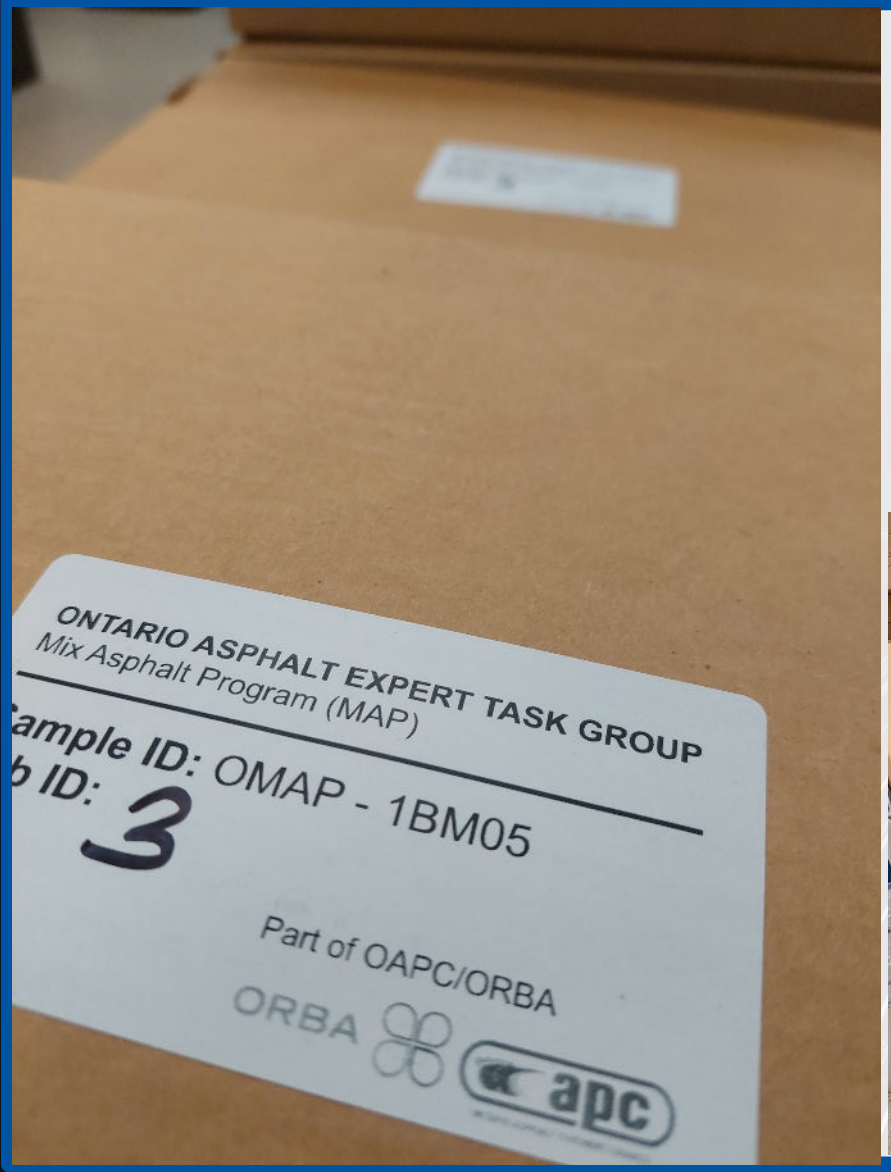
OAETG MIX ASPHALT PROGRAM (MAP)

Three (3) rounds completed

ORBA/OAPC Budget & In-Kind Contributions from members

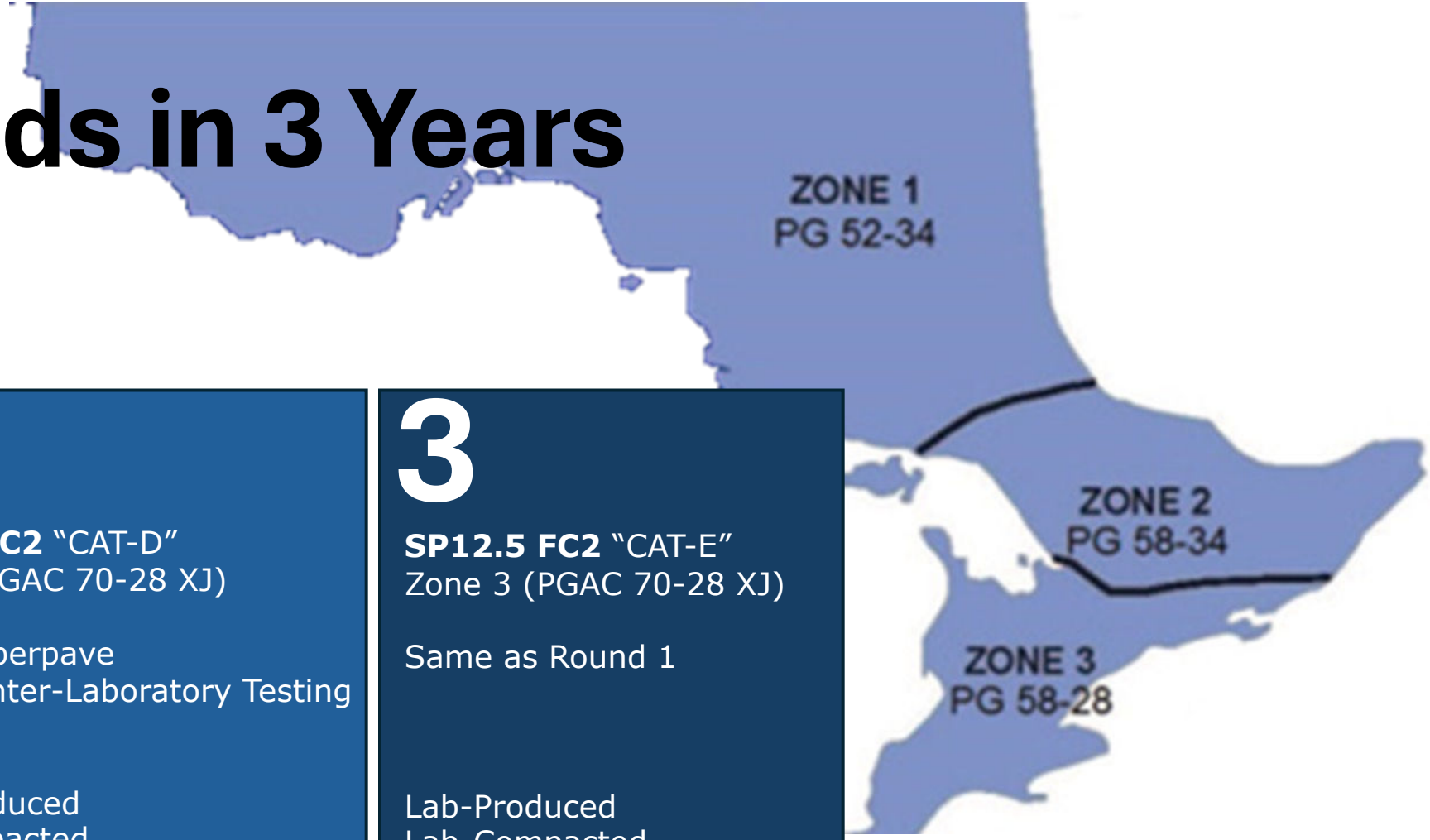
Understanding **Variability/Risk**

- Inherent variability within test method – test variability
- Interlaboratory variability
- Variability due to sampling and fabrications methods



OAETG
MIX ASPHALT PROGRAM (O-MAP)

O-MAP Rounds in 3 Years



1

SP12.5 FC2 "CAT-E"
Zone 3 (PGAC 70-28 XJ)

Contractor A & B Mixes

Plant-Produced
Lab-Compacted

3 to 4 labs participated

2

SP12.5 FC2 "CAT-D"
Zone 3 (PGAC 70-28 XJ)

MTO's Superpave
Hot Mix Inter-Laboratory Testing
Program

Plant-Produced
Lab-Compacted

4 to 6 labs participated

3

SP12.5 FC2 "CAT-E"
Zone 3 (PGAC 70-28 XJ)

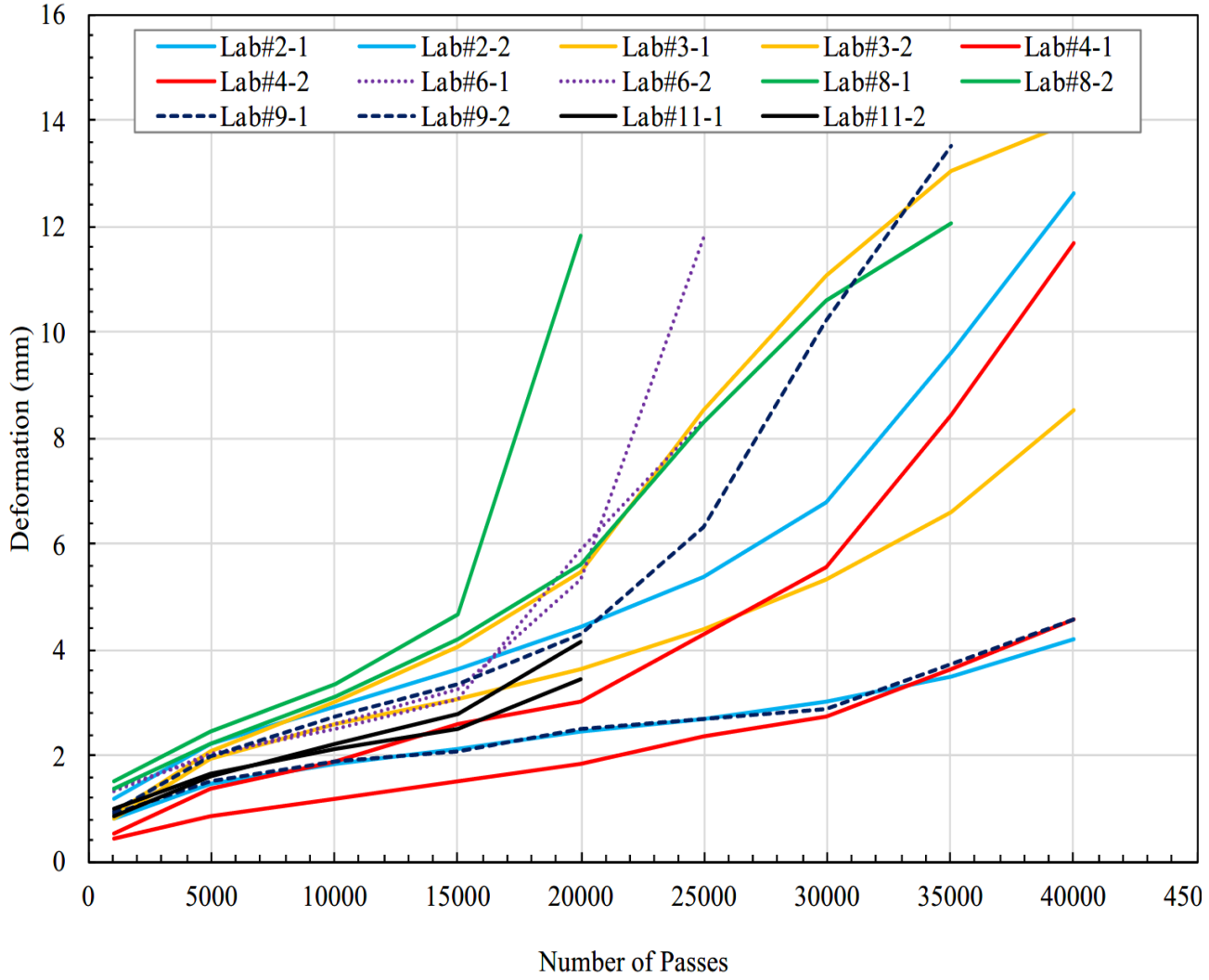
Same as Round 1

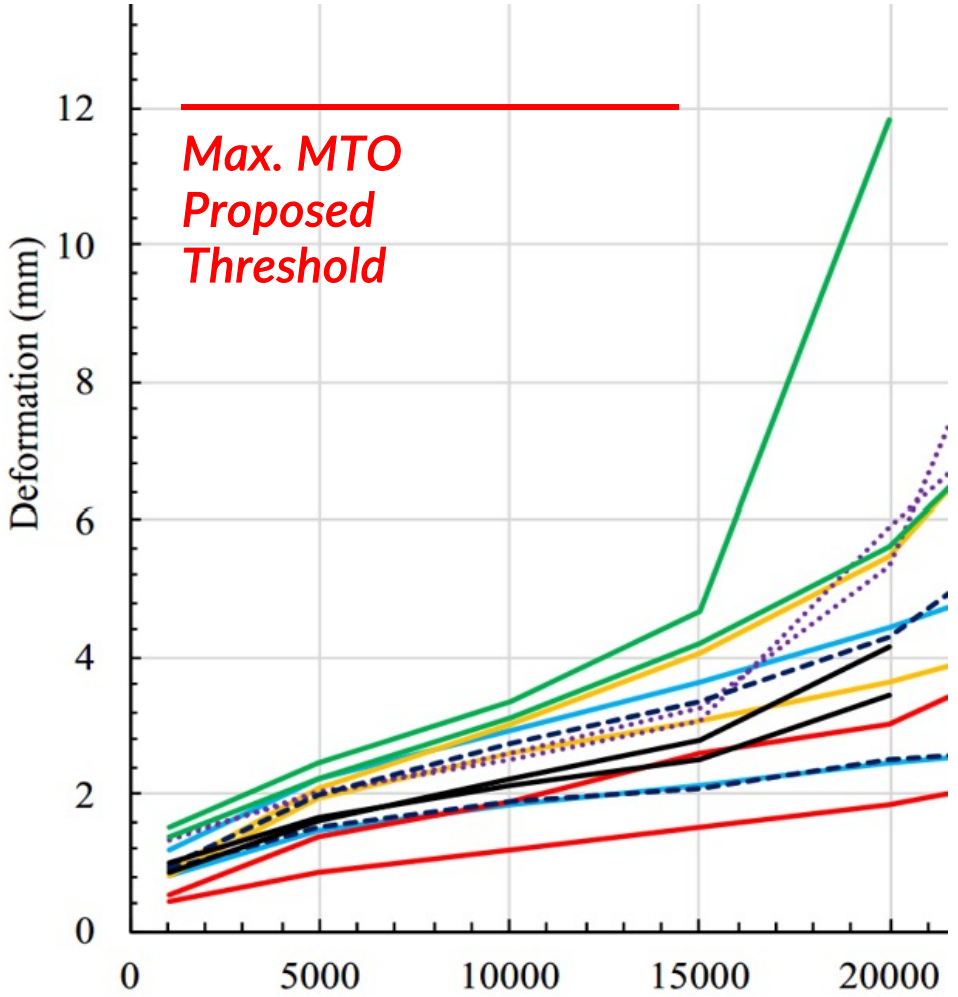
Lab-Produced
Lab-Compacted

4 to 11 labs participated

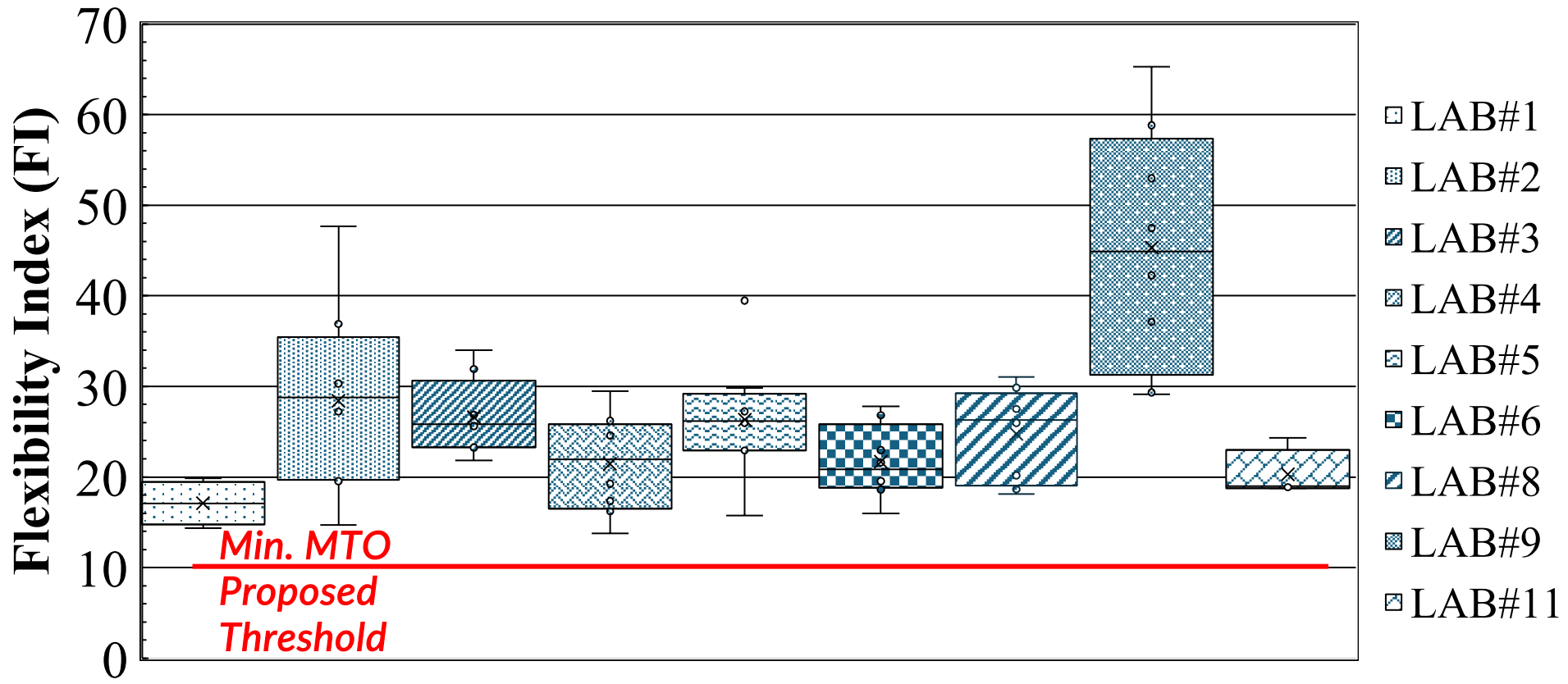
Round 3
*Included **BMD** exerscise*
*Understanding effect of **RAP** up to 30%*

HWT – Round 3


Lab#2-1
Lab#2-2
Lab#3-1
Lab#3-2
Lab#4-1
Lab#4-2
Lab#6-1
Lab#6-2
Lab#8-1
Lab#8-2
Lab#9-1
Lab#9-2
Lab#11-1
Lab#11-2
Deformation (mm)
Number of Passes
0
2
4
6
8
10
12
14
16
0
5000
10000
15000
20000
25000
30000
35000
40000
450

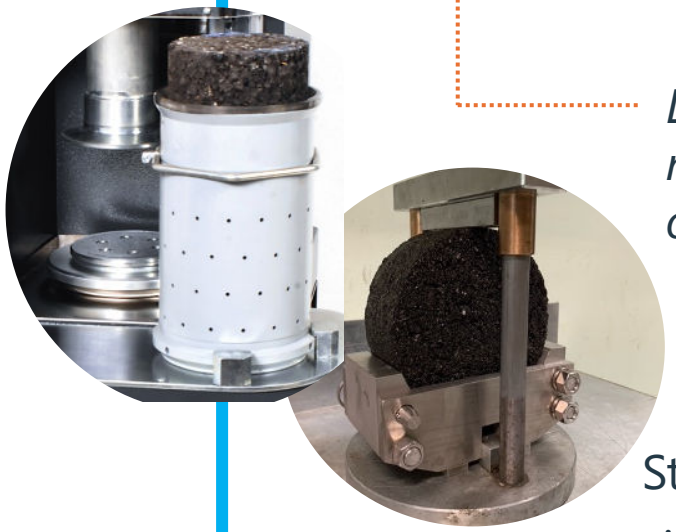

Max. MTO
Proposed
Threshold
Deformation (mm)
0
2
4
6
8
10
12
0
5000
10000
15000
20000

SCB – Round 3


Flexibility Index (FI)
70
60
50
40
30
20
10
0
Min. MTO
Proposed
Threshold
LAB#1
LAB#2
LAB#3
LAB#4
LAB#5
LAB#6
LAB#8
LAB#9
LAB#11

Variability Needs To Be Controlled Before Agency-wide Acceptance

STANDARD (AASHTO, or ASTM) *provide* ***MINIMAL GUIDANCE*** *to consistently fabricate laboratory specimens (i.e.: aging conditions and acceptance criteria) given lab can have unique way of sample prep..*



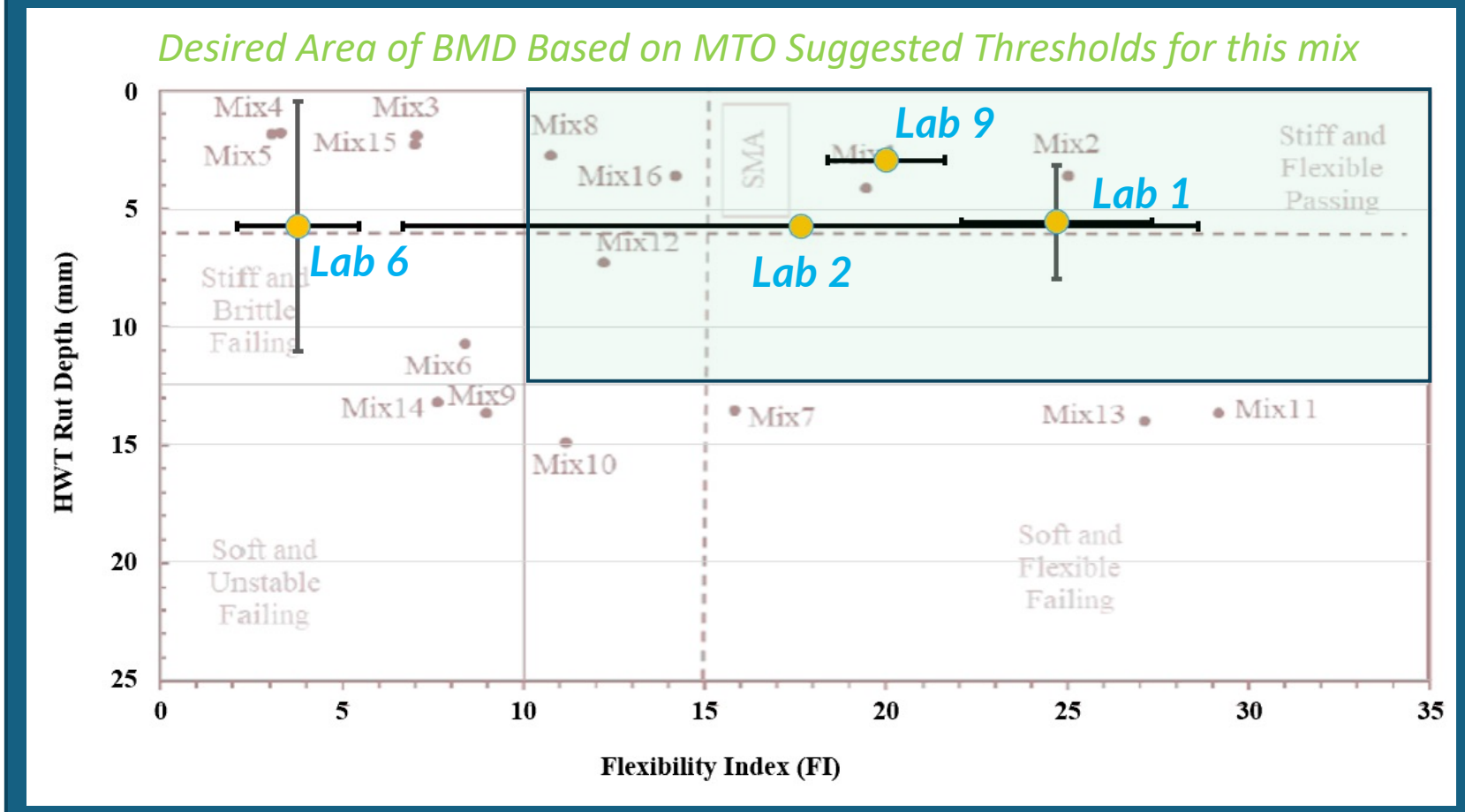
Loose asphalt mixture (laboratory or plant-produced) made into finalized test specimens for mechanical characterization.

Reheating, compaction, conditioning, cutting/ notching, air void determination, etc.

Studies have shown that different specimen **fabrication methods** can significantly **affect** measured performance properties, which will impact design, evaluation, and acceptance of asphalt mixtures

Slide Retrieved from "Industry Standardization of Asphalt Mixture Sampling Preparation and Aging for Performance Testing" CTAA 2022

EFFECT OF VARIABILITY ON "BALANCE MIX DEISGN" OUTCOME PERFORMANCE SPACE DIAGRAM (PSD)



Results superimposed over **Performance Space Diagram (PSD)** retrieved from: *Bashir I, Salehi-Ashani S, Ahmed D, Tabib S, Vasiliu G. "MTO's Experience with Post-Production Asphalt Mixture Performance Testing". Proceedings, Canadian Technical Asphalt Association, 65. 316-344 (2020).*

Mixes Studied By MTO

Mix No.	Mix Type[1]	%RAP[2] Content	Specified PGAC[3]	Traffic Category
1	SMA 12.5	-	70-28	E
2	SMA 12.5	-	70-28	E
3	SP12.5 FC2	-	70-28	E
4	SP12.5 FC2	20	70-28	E
5	SP12.5 FC2	20	70-28	E
6	SP12.5 FC2	20	64-28	C
7	SP12.5 FC2	20	64-34	D
8	SP12.5 FC2	-	64-34	E
9	SP12.5 FC2	-	58-28	D
10	SP12.5 FC2	-	58-28	D
11	SP12.5 FC1	-	58-34	D
12	SP12.5 FC1	-	58-34	D
13	SP12.5	-	58-34	C
14	SP12.5	-	52-40	B
15	SP12.5	-	52-40	B
16	SP12.5	-	52-40	C

Error bars represent one standard deviation from the average value of four replicates tested per mix (≈ 68% reliability)

MIX ASPHALT PROGRAM (MAP)

FINDINGS

Mix Properties

Mix properties do play a role in performance, especially during fabrication of HWT thinner briquets

Procedures and Instructions

Controlling consistency needed – **CCIL** or MTO technician certification required

Sample Fabrication and Testing Instructions **(SFTIs)** requires specifics on **sample heating, splitting, compaction temp. tolerances and cutting**

Collaboration

MTO and other agencies must collaborate with academia and industry in researching on sources of variability….Minimizing risk to all parties involved.

Thresholds still need to be evaluated for their practicality

Certified Technician Training Program

agencies and industry need to establish hands-on technician certification training course… through Good Roads, ORBA Academy, or Local Universities

Balancing Performance and Practicality: Implementing Balanced Mix Design In Everyday Asphalt Contracts

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Brantford, Ontario

Fan Yin, Ph.D., P.E.
Assistant Director
National Center for Asphalt Technology (NCAT), Auburn University
Auburn, Alabama

ACADEMIC WORKS IN PROGRESS

Establishing Low-Temperature Grade of Asphalt Mixtures
Using Different Practice-ready
Asphalt Mixture Performance Testing Methods

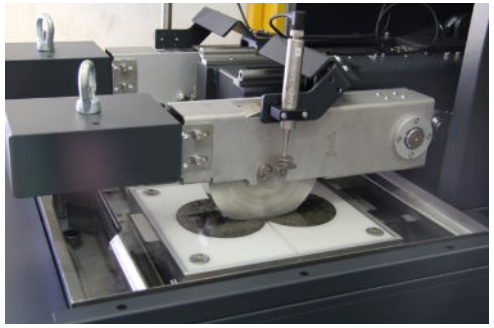
Establishing High-Temperature Grade of Asphalt Mixtures
Using Hamburg Wheel Track

Critical Evaluation of Flexibility Index
Measured Using SCB

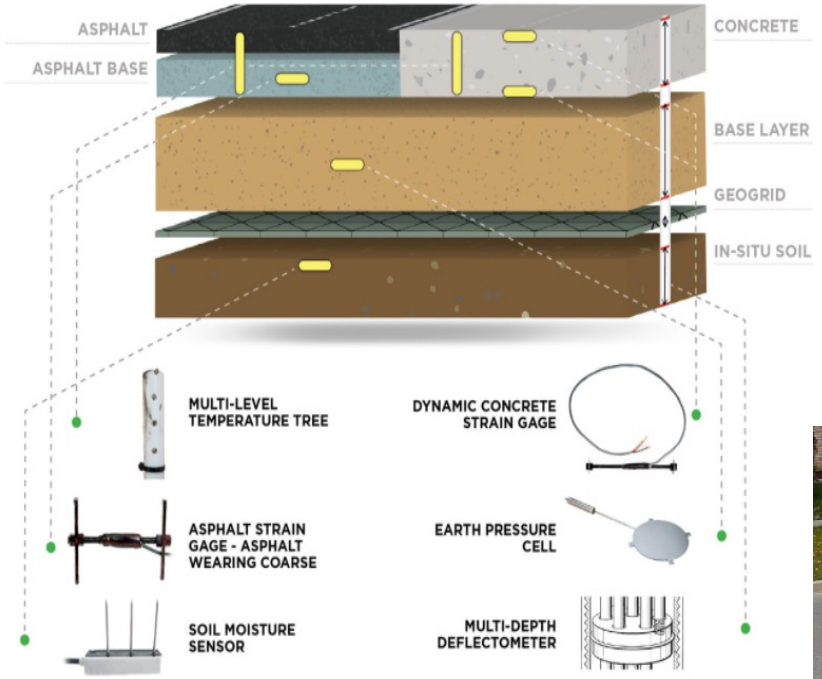
STRUCTURAL RESILIENCY

Need to Consider All Around Approach

Accelerated Loading Facilities (ALFs)



Laboratory Torture Testing



Pavement Instrumentation

MATERIALS STRENGTH

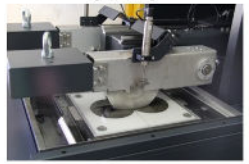
STRUCTURAL RESONSE/RESILIENCE

FIELD NON-DESTRUCTIVE EVALUATIONS

STRUCTURAL RESILIENCY

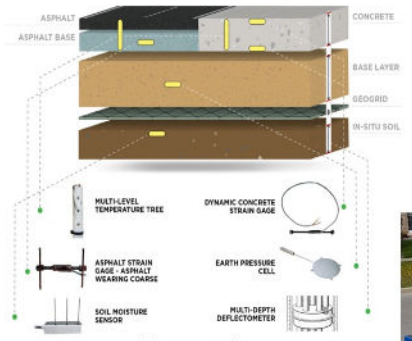
Need to Consider All Around Approach

Accelerated Loading Facilities (ALFs)



Laboratory Torture Testing

MATERIALS STRENGTH



Pavement Instrumentation

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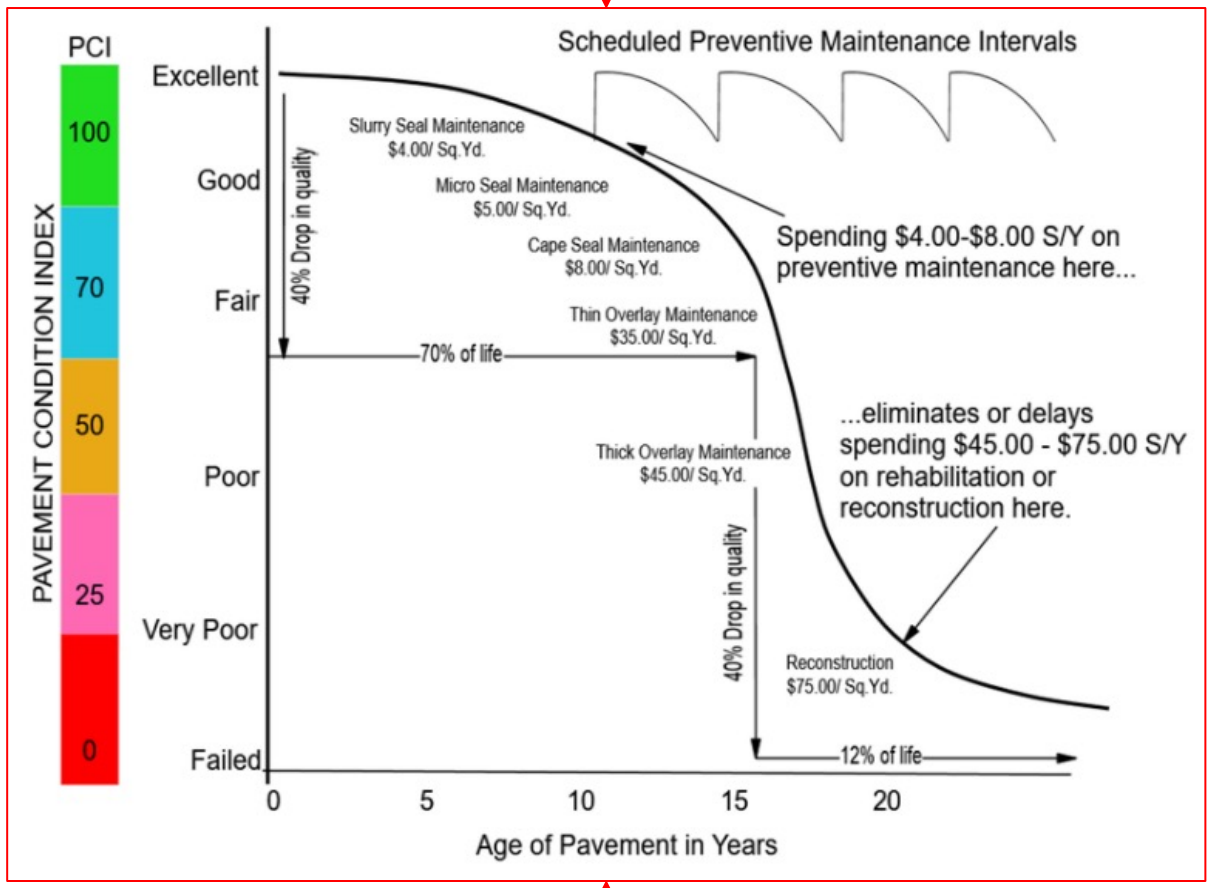

Last Few Words….
Enhancing our understanding, while being practical

1. Understand the thresholds
2. Collect at least **3-YEAR** for "information only" testing as part of **MIX DESIGN SUBMISSION**
3. Understand efforts required in coarse and fine-tunning phases of thresholds – **avoid any desperate changes** to mix design to just pass the test (i.e. aggregate changes, PGAC and etc.)
4. Request **PERFORMANCE-VERIFIED MIX DESIGN SUBMISSION**
5. Control the Performance throughout the contract using traditional Quality Assurance Measures (i.e. gradation and AC%)
6. **ONLY** do performance testing on plant-produced, field retained, and field compacted if **Forensics** required

QUESTIONS

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