PERFORMANCE BENCHMARKING LESSONS LEARNED ON ASPHALT AIRFIELD MIXTURES

at Toronto Pearson International Airport

Presenter: Salman Bhutta, Ph.D., P.Eng.

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Location: SWIFT 2023 - Winnipeg

Engtec Consulting Inc.

Toronto Pearson

ACKNOWLEDGMENT

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- Greater Toronto Airports Authority
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- Avia NG Airport Consultants
- Dufferin Construction Company

OUTLINE

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- Asphalt Mix Challenges at Pearson Airport.
- Volumetrically-Balanced and Performance Verified Hot-mix Asphalt mixes.
- Experimental Work and Findings.
- Next Steps.
- Remarks and Questions.

Toronto Pearson – Canada's Largest Airport

Toronto Pearson

INTRODUCTION

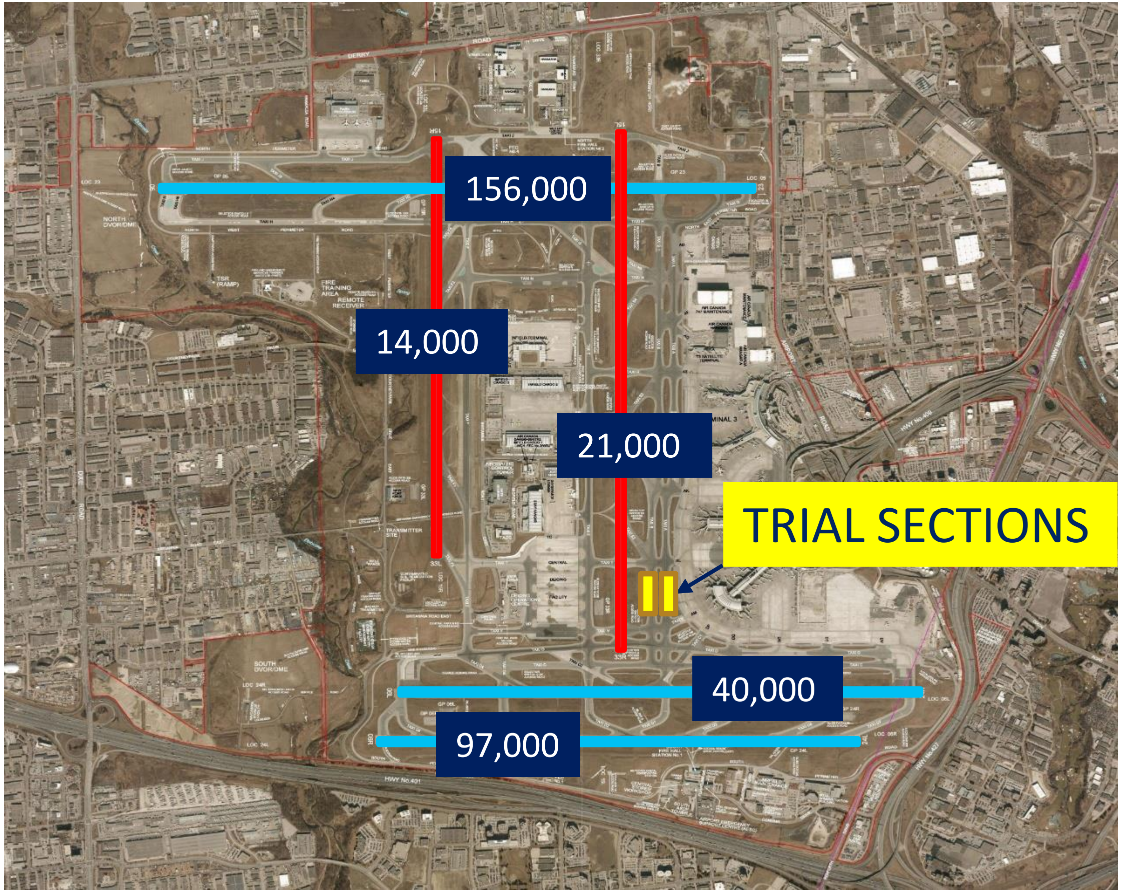
- 2022 Passenger Volume ------------------------ 35.6 Million PAX.
- Ranking in North America* -------------------- 2nd busiest airport
- Total airside paved areas ----------------------- approx. 5.8 million m^2
- # of aircraft movements **--------------------- approx. 336,800
- Cargo processed ***------------------------------ 388,700 M.T.
- Direct Jobs created --------------------------------50,000
- GDP contribution to Ontario -------------------$42 Billion CAD

** In terms of international passengers, 29.6 Million PAX prior to COVID.*

*** 2022 Data*

**** 2020 Data*

Toronto Pearson – Canada's Largest Airport



2022
Traffic
Movement

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ASPHALT MIX CHALLENGES AT GTAA

- Effects of new large aircraft with higher tire pressure and higher maximum takeoff weight.
- Slow moving aircraft with stop and go movement prior to or at the holding bay areas, stop bar areas, etc.
- Global warming impact leading to unusually severe hot weather in the summer(s).
- Maintaining the **integrity** and **safety** of the airport's daily operation is a **must** for all travelers and stakeholders.

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ASPHALT MIX CHALLENGES AT GTAA

GTAA's Proactive Approach:

- Innovative opportunities such as:
  - Volumetrically-Balanced and Performance-Verified Hot-mix Asphalt mix
  - Jet Fuel Resistant mix.
  - Fiber and Wax Additive mix.
  - Warm Mix Asphalt technology.
  - Dual layer asphalt paving equipment (Integral Paving).
  - Perpetual pavement design, etc. to improve mix design to provide durable pavement and to minimize operational impacts due to planned/unplanned shutdown.

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ASPHALT MIX CHALLENGES AT GTAA

GTAA's Proactive Approach:

- Using **Premium** materials for better durability and frictional properties.
- More collaboration with contractors, suppliers and experts in area of paving design and paving technology.
- More collaboration with airframe manufacturers to ensure that aircraft design for future large aircraft will have no negative impact to current/existing pavement due to load, tire pressure, gear configuration, etc.

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ASPHALT MIX CHALLENGES AT GTAA

GTAA's Proactive Approach:

- More collaboration with other Airports and Universities for knowledge exchange (i.e. Canadian Airfield Pavement Technical Group (CAPTG) and University of Waterloo Centre for Pavement and Transportation Technology (CPATT)).

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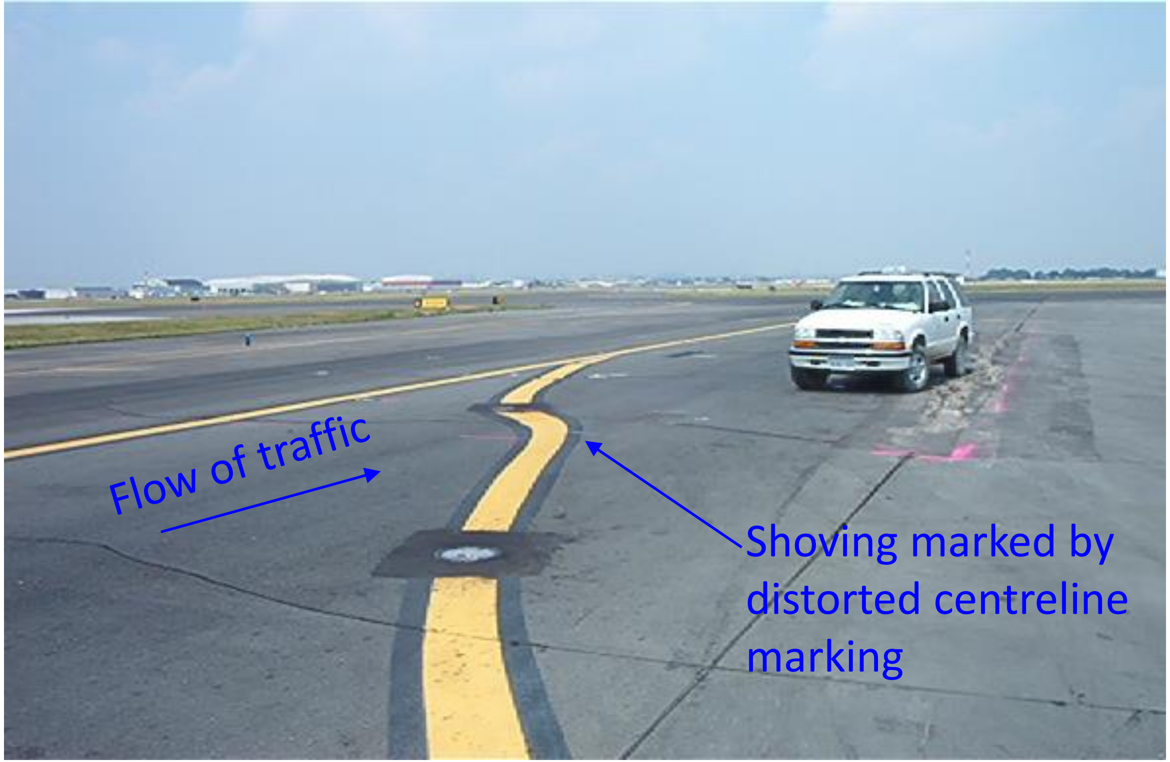
ASPHALT MIX CHALLENGES AT GTAA



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FOUR KEY CHALLENGES:

- Design methods rely heavily on volumetrics and mechanical strength tests
- 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:
  - PGAC binders, RAP, WMA additives etc.
- Rely on field performance (with many years in service) to “proof” changes/modifications

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STUDY OBJECTIVES

- Collaborative work between GTAA, Engtec, Avia NG and Dufferin.
- Volumetrically-Balanced and Performance verified asphalt mix to enhance the durability of the asphalt mixes.
  - Task 1 – Volumetric Design of GTAA Surface and Lower Courses using Superpave method with Trap Rock, Diabase and Gabbro and Lime Stone source aggregates
  - Task 2 – Performance Benchmarking to baseline the Overall Stiffness, Permanent Deformation, Fatigue, Thermal Cracking, Performance Space Diagram and Field Trials
  - Task 3 – Balanced Mix Designs
  - Task 4 – Extreme Events Resiliency

PERFORMANCE BENCHMARKING

1 Recipe & Volumetric Selection

2 Performance-Verified Volumetric Design

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

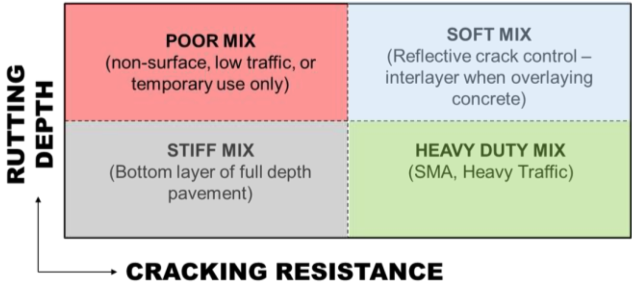
3 Performance-Modified Volumetric Design

Adjustment of mix proportions to resist a specific distress
Example: Mix Proportioning, PGAC Type, materials etc.

4 Performance-Based Design

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

Mix Durability Matrix



Vs.

PERFORMANCE BENCHMARKING

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Scope of Task 1 Study

1 Recipe & Volumetric Selection

2 Performance-Verified Volumetric Design

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

3 Performance-Modified Volumetric Design

Adjustment of mix proportions to resist a specific distress
Example: Mix Proportioning, PGAC Type, materials etc.

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STUDIED MIXES

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Aggregate and PGAC supplied by local contractors

- 100 percent crushed Surface Course Mix aggregates that provide high level of hydrophobic behaviour in terms of moisture resistivity and asphalt binder compatibility.
  - Mineralogy of Trap Rock, Diabase, Gabbro- *Premium Sources for Surface Course*.
- 100% Crushed Limestone Materials for Base Asphalt for both Coarse and Fine Aggregates.
  - Dolostone (also known as Dolomitic) – *Tried and Tested Materials for Heavy Duty Binder Course asphalt.*
- PGAC samples of two grades of PGAC 70-28J and 64-28J - *Polymer Modified.*

MARSHALL MIXES - GTAA

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- The GTAA mix designs for both surface and lower course mixes are mainly governed by the minimum AC content of 5.3 percent, using 75 blows of Marshall hammer per side.
- Range of 3.0 to 5.0 percent air voids allowed for the design, the GTAA mix is preferably accepted at mid-range of 4.0 percent air voids.
- The minimum AC content was historically specified at 5.0% in 2014 and gradually increased to 5.3% to ensure durability and better performance.

MOVING TO SUPERPAVE

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- Similar aggregate skeleton as pervious mixes (Marshall).
- N_{design} of 125 (Superpave) typically equate to 75 blows per side (Marshall).
- Selecting N_{design} of 75 did raise initial concerns, as this category represents low to moderate volume traffic.
- The perception is that airfield mixes would require higher levels of design gyrations representing higher compaction characteristics for superior performing mixes, which was not necessarily reflected by the results of this study.

No of Gyrations	Air Voids Percentage (%) Per Mix Type at Varying Gyration Levels				
	SP 12.5FC2 Gabbro	SP 12.5FC2 Diabase	SP 12.5FC2 Trap Rock	SP19 Dolostone 1	SP19 Dolostone 2
50	5.4	5.6	5.3	5.5	5.5
75	**4**	**4.2**	**4.4**	**4.2**	**4**
100	3.2	3.5	3.8	2.7	3
125	2.6	2.7	2.8	1.9	2.2

SUPERPAVE SURFACE MIXES

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Function	Sieve Size (mm)	SP 12.5 FC2 Trap Rock	SP 12.5 FC2 Gabbro	SP 12.5 FC2 Diabase
Gradation Percent (%) Passing	19.0	100	100	100
	12.5	97.4	96.3	95.7
	9.5	82.4	83.2	81.4
	4.75	55.6	55.9	55.4
	2.36	47.0	41.0	43.2
	1.18	33.6	28.9	27.8
	0.600	21.0	19.9	17.5
	0.300	11.1	12.4	11.2
	0.150	6.7	6.8	7.0
	0.075	5.0	4.1	5.0

Properties	SP 12.5 FC2 Trap Rock	SP 12.5 FC2 Gabbro	SP 12.5 FC2 Diabase
Binder Content (%)	5.3	5.3	5.3
Design Air Voids (%)	4.0	4.0	4.0
Voids in the Mineral Aggregate (%)	16.3	16.6	16.8
Film Thickness, µm	10.9	12.2	11.8
Tensile Strength Ratio (TSR), %	86.8	85.8	85.2

SUPERPAVE BINDER MIXES

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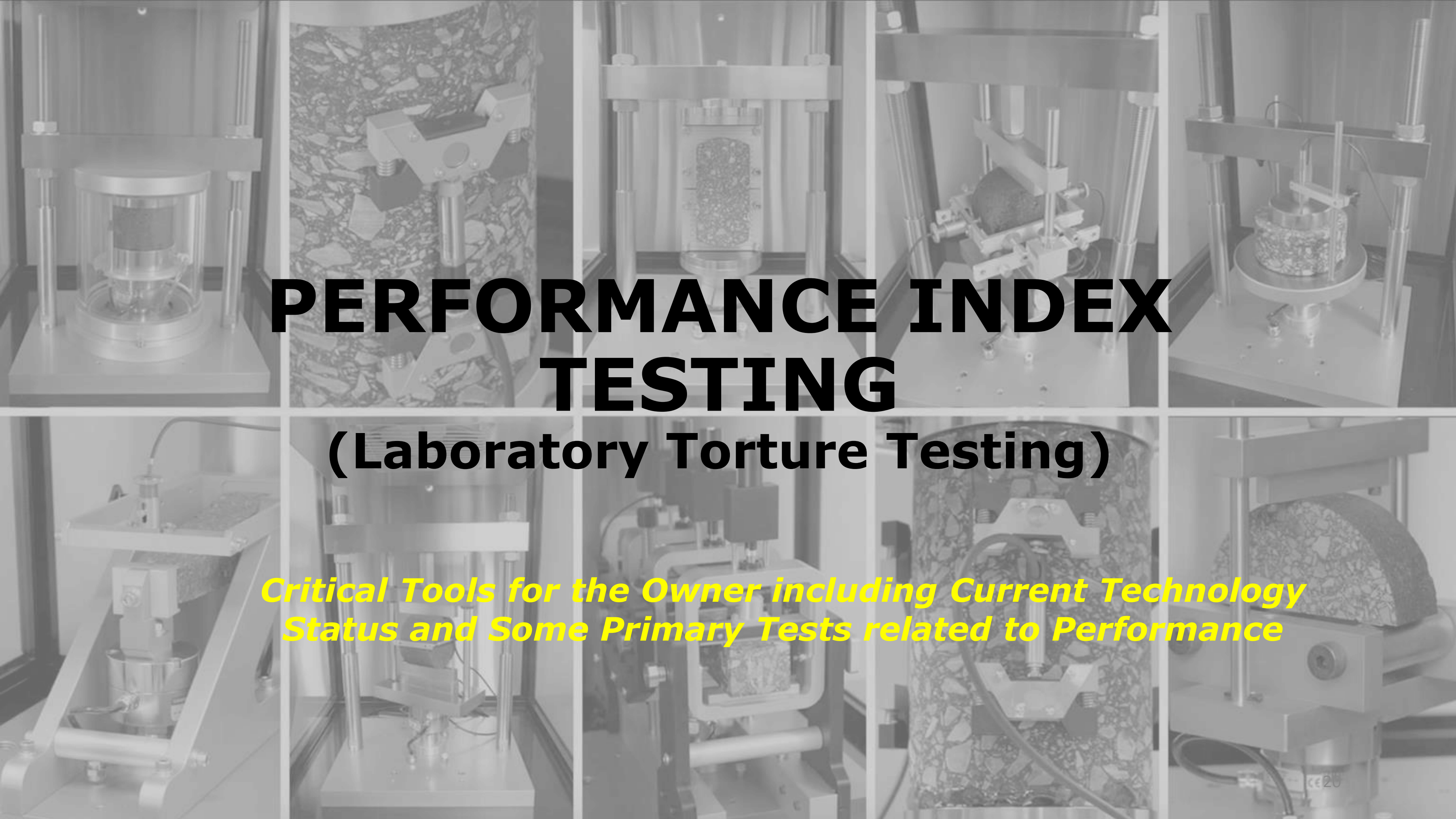
Function	Sieve Size (mm)	Superpave 19.0 Dolostone 1	Superpave 19.0 Dolostone 2
Gradation Percent (%) Passing	25.0	100.0	100.0
	19.0	96.4	94.6
	12.5	79.9	79.4
	9.5	67.0	63.1
	4.75	47.9	48.5
	2.36	37.4	38.3
	1.18	26.3	25.6
	0.600	15.7	15.0
	0.300	7.9	8.3
	0.150	5.7	5.4
	0.075	4.2	4.3

Properties	Superpave 19.0 Dolostone 1	Superpave 19.0 Dolostone 2
Binder Content (%)	5.3	5.3
Design Air Voids (%)	4.0	4.0
Voids in the Mineral Aggregate (%)	15.4	13.4
Film Thickness, µm	12.2	9.9
Tensile Strength Ratio (TSR), %	84.6	87.2



PERFORMANCE INDEX TESTING

(Laboratory Torture Testing)

Critical Tools for the Owner including Current Technology Status and Some Primary Tests related to Performance

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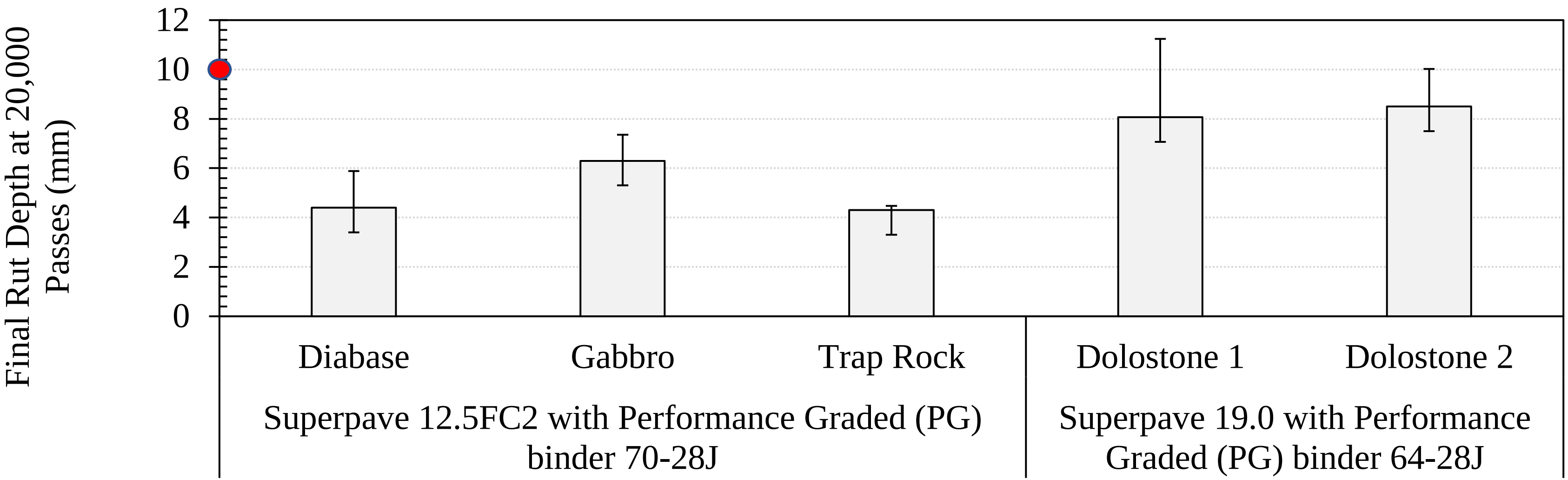
EVALUATING

RUTTING
SHOVING

POTENTIAL

Prof. Al-Qadi (University of Illinois Urbana-Champaign Department of Civil and Environmental Engineering researchers visit the Federal Aviation Administration's William J. Hughes Technical Center in Atlantic City, New Jersey)

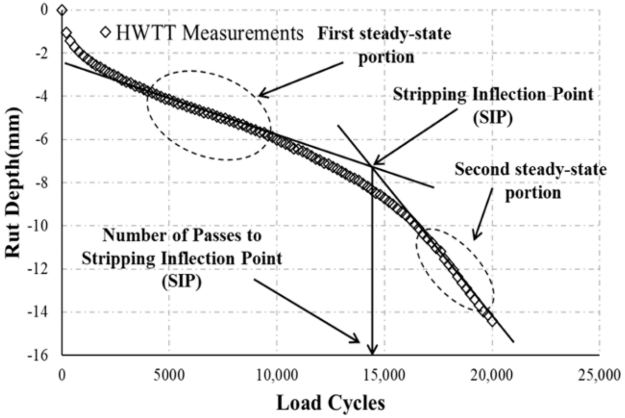
HAMBURG RUT WHEEL TRACK

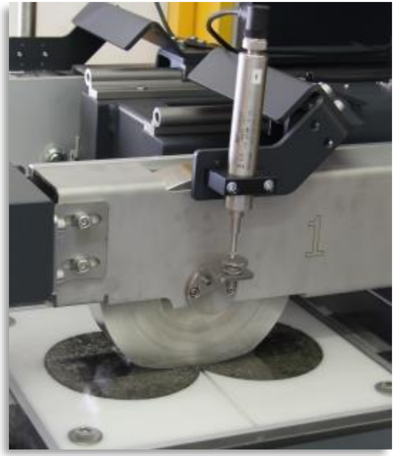


1. FAA recommends 50°C and 10mm max rut
2. For airfield mixes: minimum 0.3% Antistripping Agent, 1% Hydrated Lime, or combination of both recommended

HAMBURG RUT WHEEL TRACK

- **AASHTO T 342 – Hamburg Rut Wheel Test**
- Tracking 705 N of load wheel for 20,000 passes or more
- Submerged at varying high temperature
- Range between 40°C to 50°C
- FAA recommends 50°C and 10mm max rut





Conventional Before and After

GTAA - Before and After


LOW TEMPERATURE CRACKING
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DCT – THERMAL CRACKING

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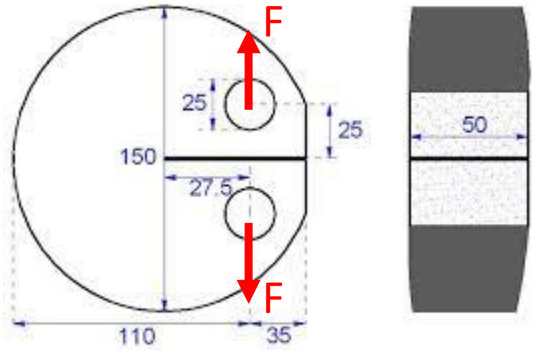
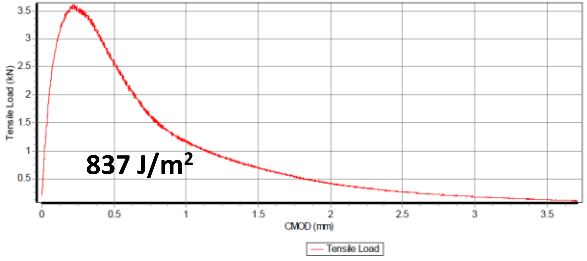
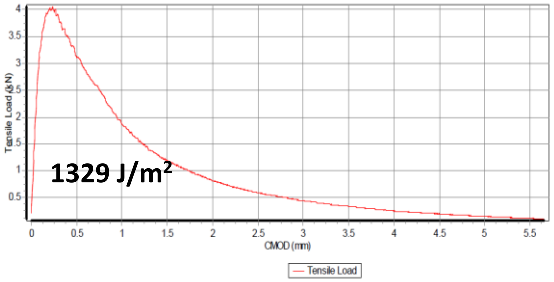


- **ASTM D7313 - Disc-Shaped Compact Tension**
- Gyratory-sized
- Performed at 10°C higher than Low PG grade (i.e. -18°C)
- Captures fracture energy and relaxation of the mix at colder conditions

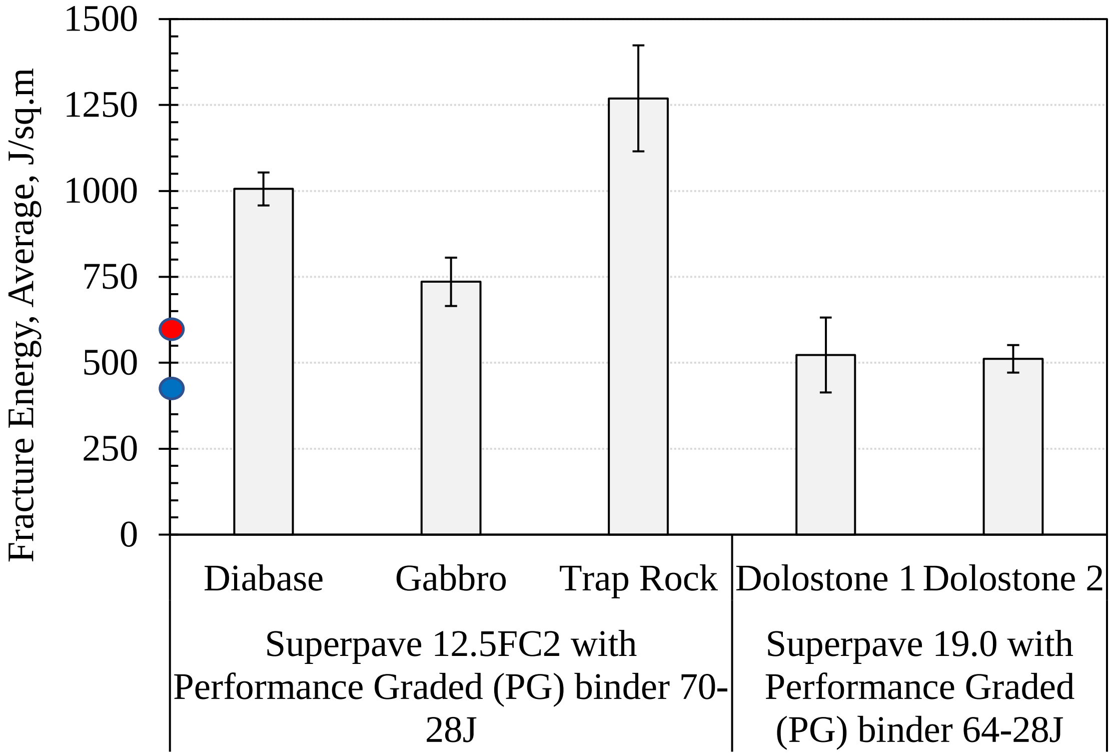


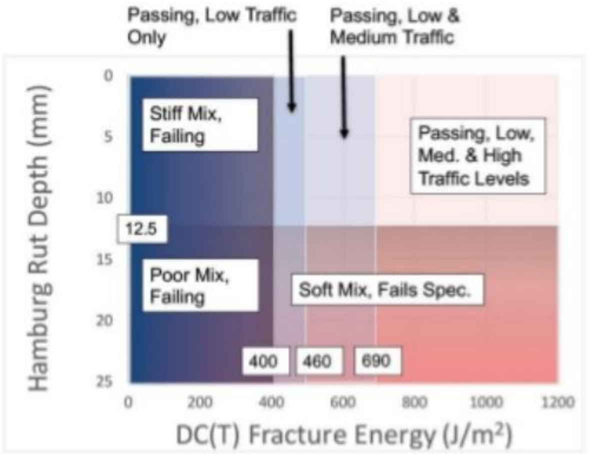
Conventional



GTAA

LOW TEMPERATURE CRACKING





Managing Performance of High Recycle Asphalt Mixtures

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

EVALUATING FATIGUE

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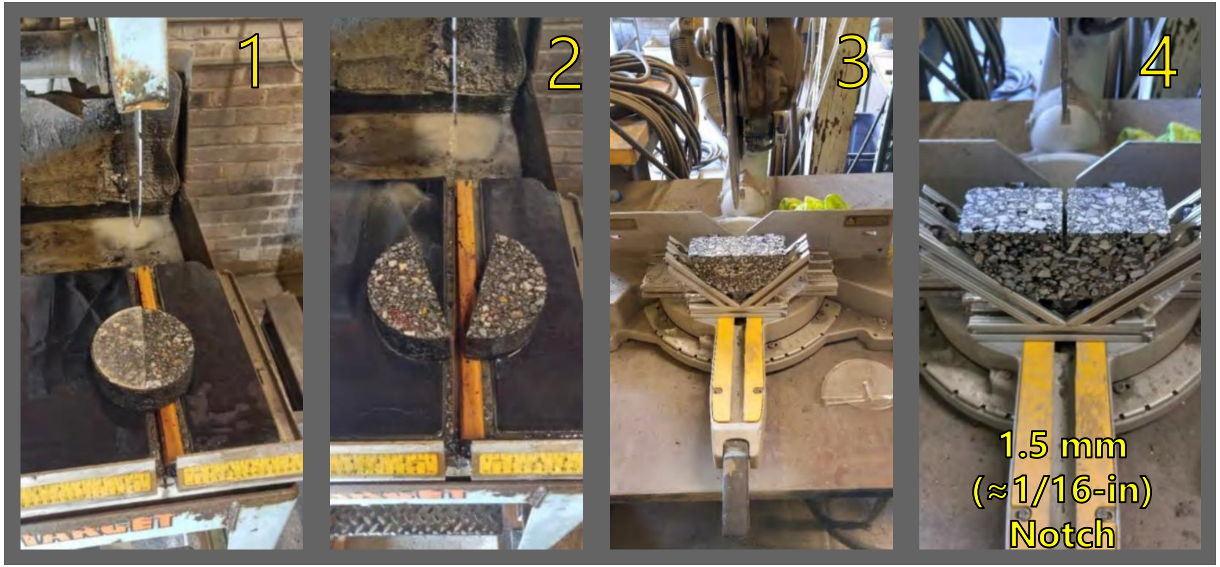
SCB CRACKING RESISTANCE (I-FIT)

- **AASHTO T 393 – Semi Circle Bend Test**
- Gyratory-sized (H 50 mm X D 150 mm)
- Performed at 25°C or lower



SCB CRACKING RESISTANCE (I-FIT)

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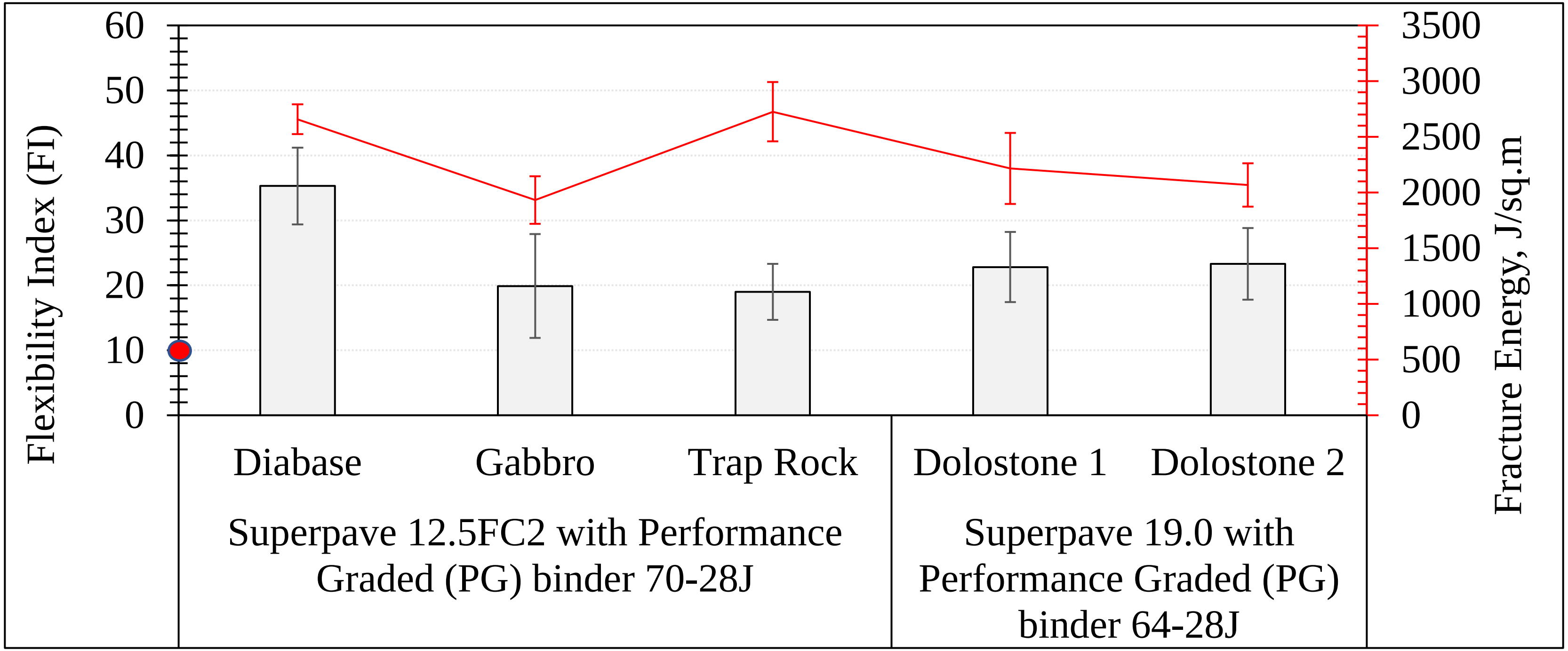

DYNAMIC MODULES

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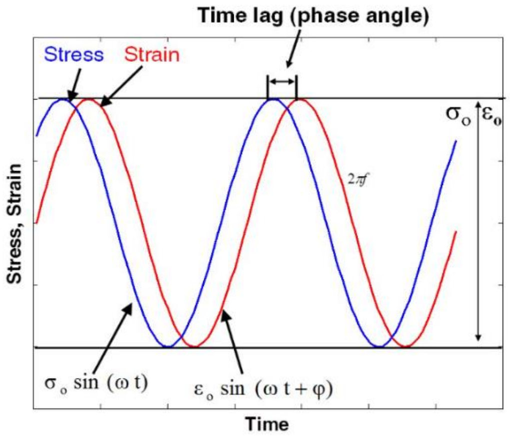
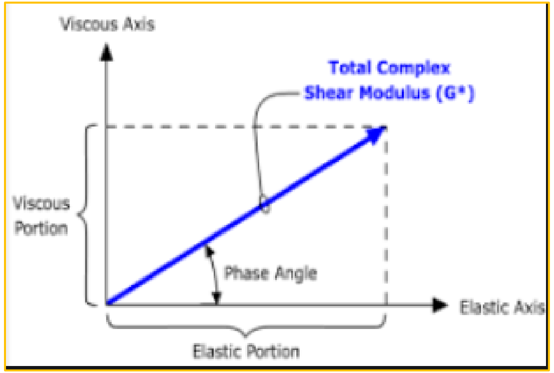
- **AASHTO T 378 or T 342**
- Overall Mix Stiffness
- Performed at varying temps and frequencies
- Material input to pavement design (MEPDG)



Complex Modulus



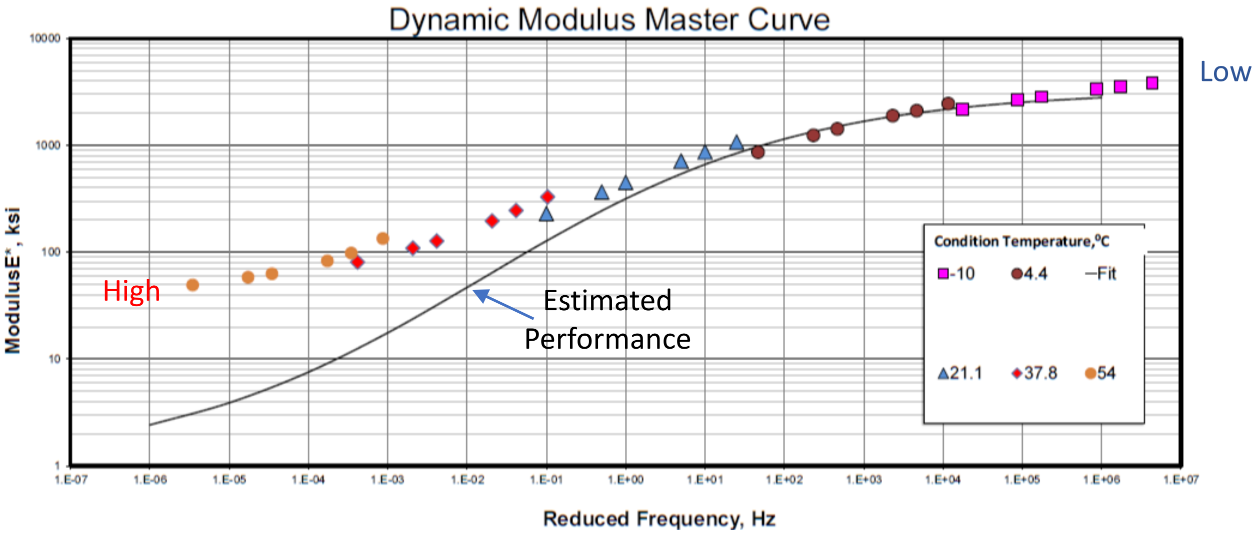
$$|E^*| = \frac{\sigma_o}{\varepsilon_o}$$

DYNAMIC MODULES

Temp. (°C) "Climate"	-10 Thermal	21.1 Fatigue	54 Rutting

Freq. (Hz) "Traffic Speed"	0.1 (Very Slow)	0.50	1.0	5.0	10.0 (Moderate)	25.0 (High Speed)

- The findings from this study provided that all surface mixes and binder mixes are expected to perform relatively the same, when it comes different temperature and loading frequency conditions



1 ksi = 6.895 MPa

PERFORMANCE SPACE DIAGRAM (PSD)

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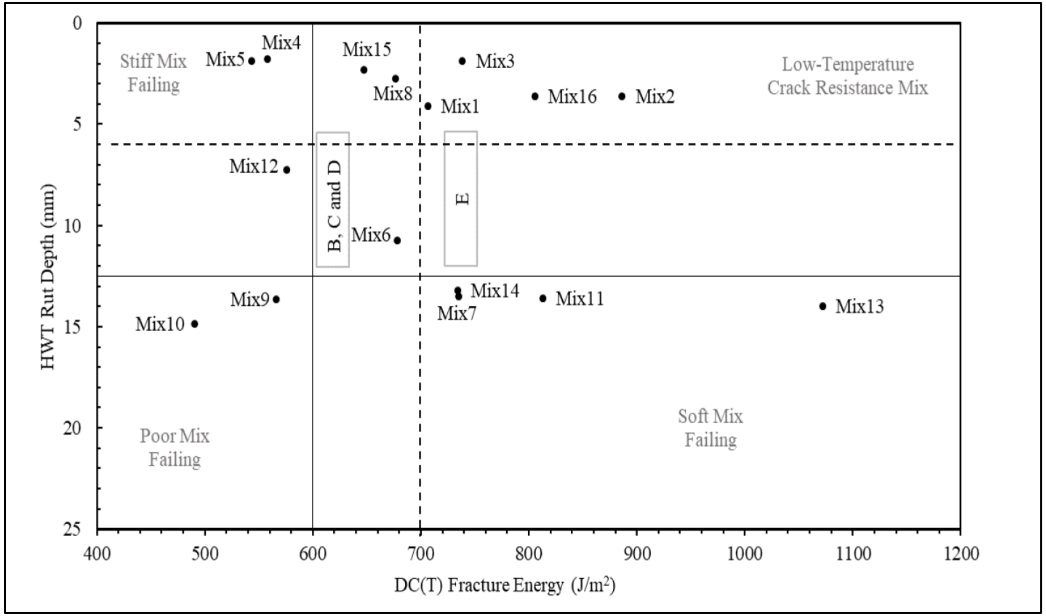
- PSD Example Developed by the Ministry of Transportation in Ontario, showing Rut Depth using the Hamburg Wheel Tracking (**HWT**) device versus low temperature cracking fracture energy using the Disk-Compact Tension Test (**DCT**).
- This PSD was used to evaluate GTAA mixes.



PERFORMANCE SPACE DIAGRAM (PSD)

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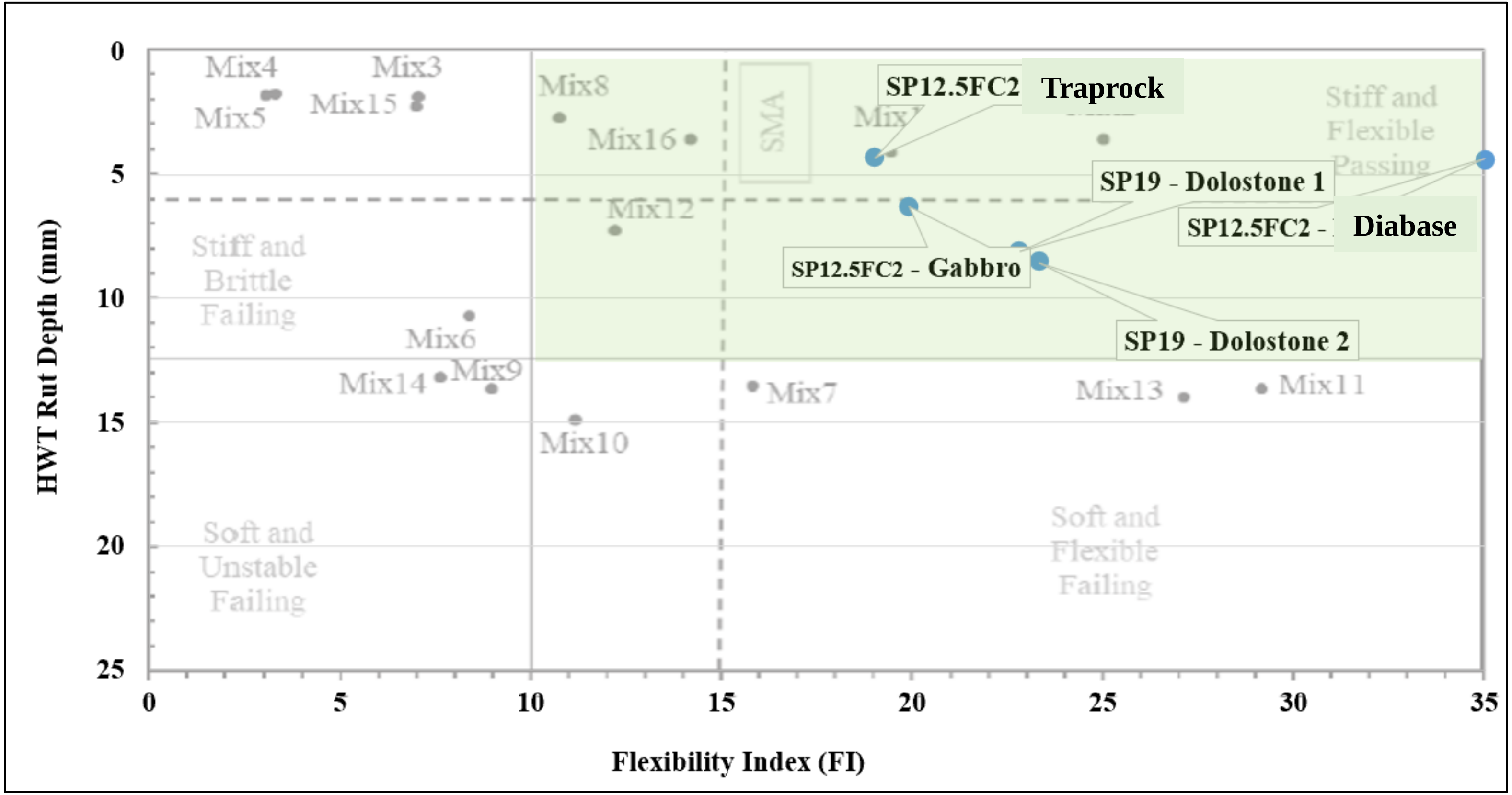

PERFORMANCE SPACE DIAGRAM (PSD)

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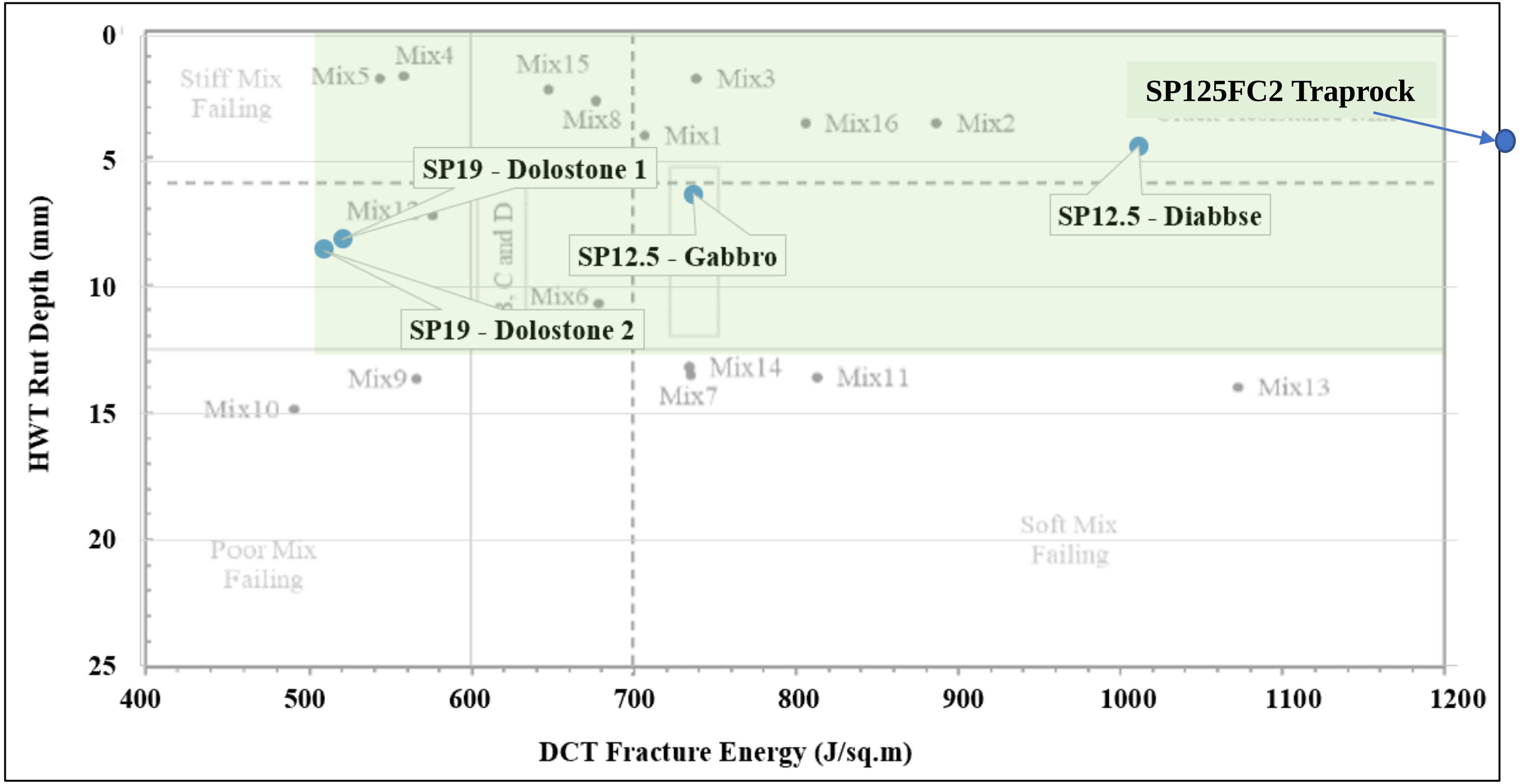

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Field Trials

- 4 trials are planned to be done in fall on Alpha and Bravo Taxiways including a Control Section,
  - **Trial 1**: Volumetric Lower Course with Regular Surface Course, approx. 250M.T.
  - **Trials 2 & 3**: Volumetric Lower Course with Volumetric Surface Course together, approx. 250M.T. + 250M.T.
  - **Trial 4**: Regular Lower Course with Volumetric Surface Course, approx. 250M.T.
  - **Control Section**: Regular Lower Course and Surface Course

PERFORMANCE BENCHMARKING

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Next Steps

- Update and adjust the Balanced Mix Design based on the Field Trial results as required.
- Additional temperatures testing would be considered to establish mix sensitivity to extreme climatic events at the balanced asphalt content.
- Finally, risk from fuel spills and/or glycol chemical could be studied by performing P-404 Fuel Immersion Test.

REMARKS & QUESTIONS

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