

ADVANCING BALANCED MIX DESIGN A MULTI-YEAR STUDY

at Toronto Pearson International Airport



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Date: September 23, 2025

Location: SWIFT 2025 – Niagara Falls



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OUTLINE

- Asphalt Mix Challenges at the Airport

- Summary of Volumetrically-Balanced and Performance-Verified Asphalt Mix Findings

Presented in
2023 SWIFT

- Balanced Mix Designs
 - Extreme Events Resiliency
 - Experimental Work and Findings
 - Field Trials
 - Remarks and Questions
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TORONTO PEARSON – Canada’s Largest Airport

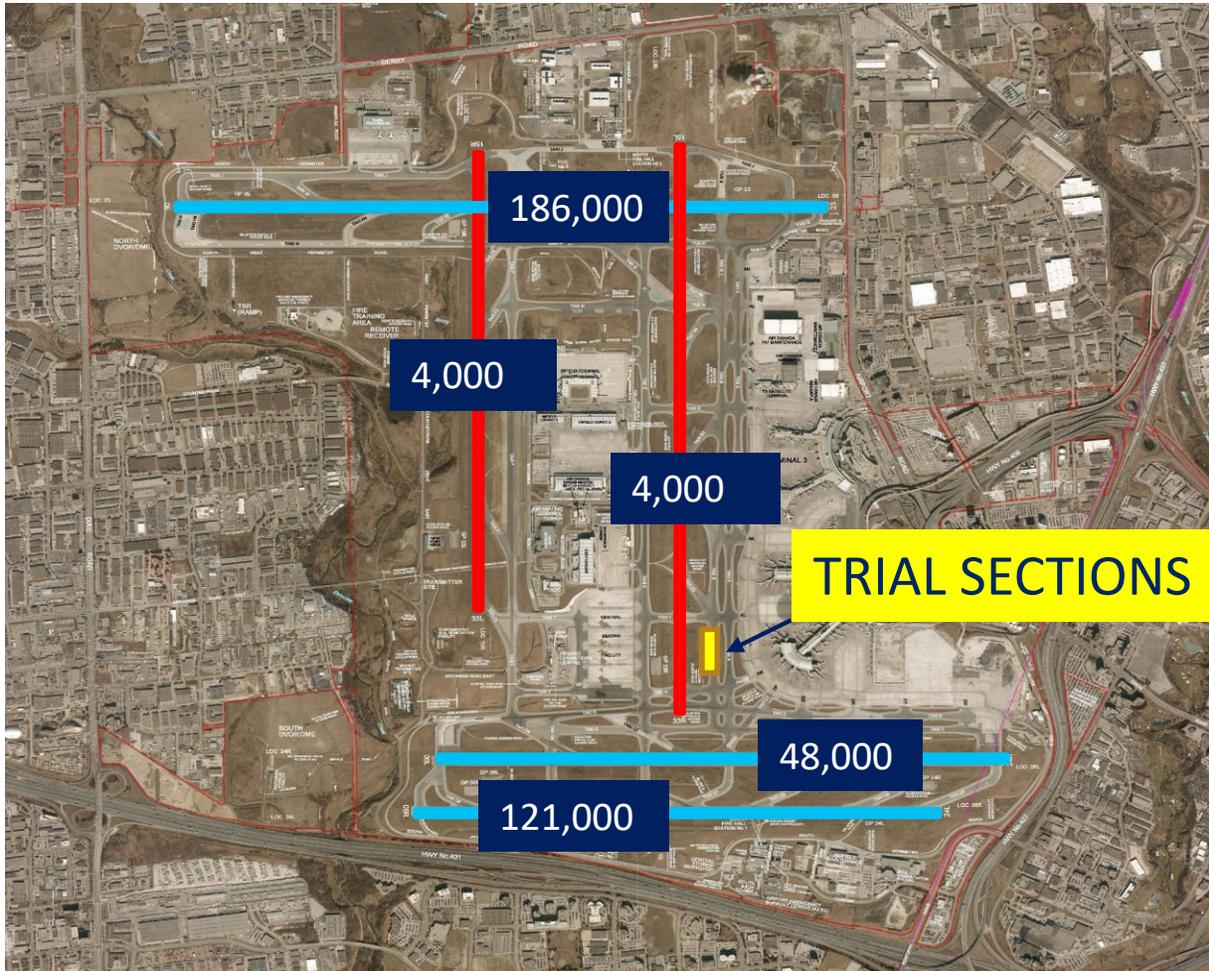
INTRODUCTION

- 2024 Passenger Volume ----- 46.8 Million PAX.
- Ranking in North America* ----- 2nd busiest airport
- Total airside paved areas ----- approx. 5.8 million m²
- # of aircraft movements ----- approx. 363,000
- Cargo processed **----- 429,500 M.T.
- Direct Jobs created ----- 50,000
- GDP contribution to Ontario ----- \$42 Billion CAD

* In terms of international passengers, 30.4 Million PAX in 2024.

** Statistics Canada, Aviation Data Visualization Hub: Airport Activity Cargo 2024 Data

TORONTO PEARSON – Canada's Largest Airport



2024
Traffic Movement
Data

ASPHALT MIX CHALLENGES AT THE AIRPORT

- 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).
 - Insufficient inspections and tests to ensure aspects like materials, surface preparations, etc. meet contract requirements.
 - 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 THE AIRPORT

GTAA's PROACTIVE APPROACHES:

- Using Premium materials for better durability and frictional properties.
 - Hiring the most qualified, reliable and experienced contractor.
 - Implement full time quality assurance to set quality standards to be followed across the project lifecycle.
 - More collaboration with contractors, suppliers and experts in area of paving design and paving technology.
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ASPHALT MIX CHALLENGES AT THE AIRPORT

GTAA's PROACTIVE APPROACHES:

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

ASPHALT MIX CHALLENGES AT THE AIRPORT

GTAA's PROACTIVE APPROACHES:

- Innovative opportunities such as:
 - Volumetrically-Balanced and Performance-Verified Hot-mix Asphalt mix(s).
 - 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.

FOUR KEY CHALLENGES

- Design methods heavily rely 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 prove changes/modifications
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STUDY OBJECTIVES

- 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 Limestone source aggregates
 - Task 2 – Performance Benchmarking to baseline the Overall Stiffness, Permanent Deformation, Fatigue, Thermal Cracking, Performance Space Diagram(s) and Field Trials
 - Task 3 – Balanced Mix Designs
 - Task 4 – Extreme Events Resiliency
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ASPHALT MIXTURE

Considering Performance in Mixture Design

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

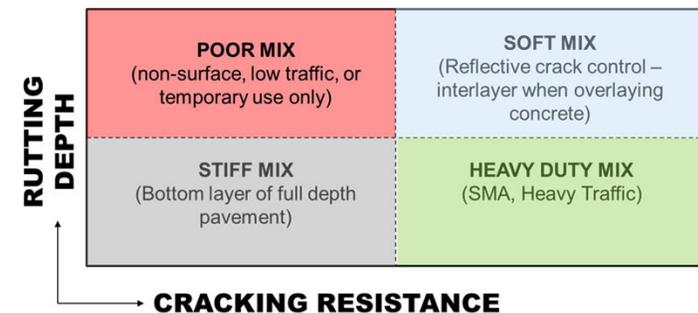
3 Performance-Modified Volumetric Design

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 Mix Volumetric Improvement

Mix Durability Matrix



Vs.



ASPHALT MIXTURE

Considering Performance in Mixture Design

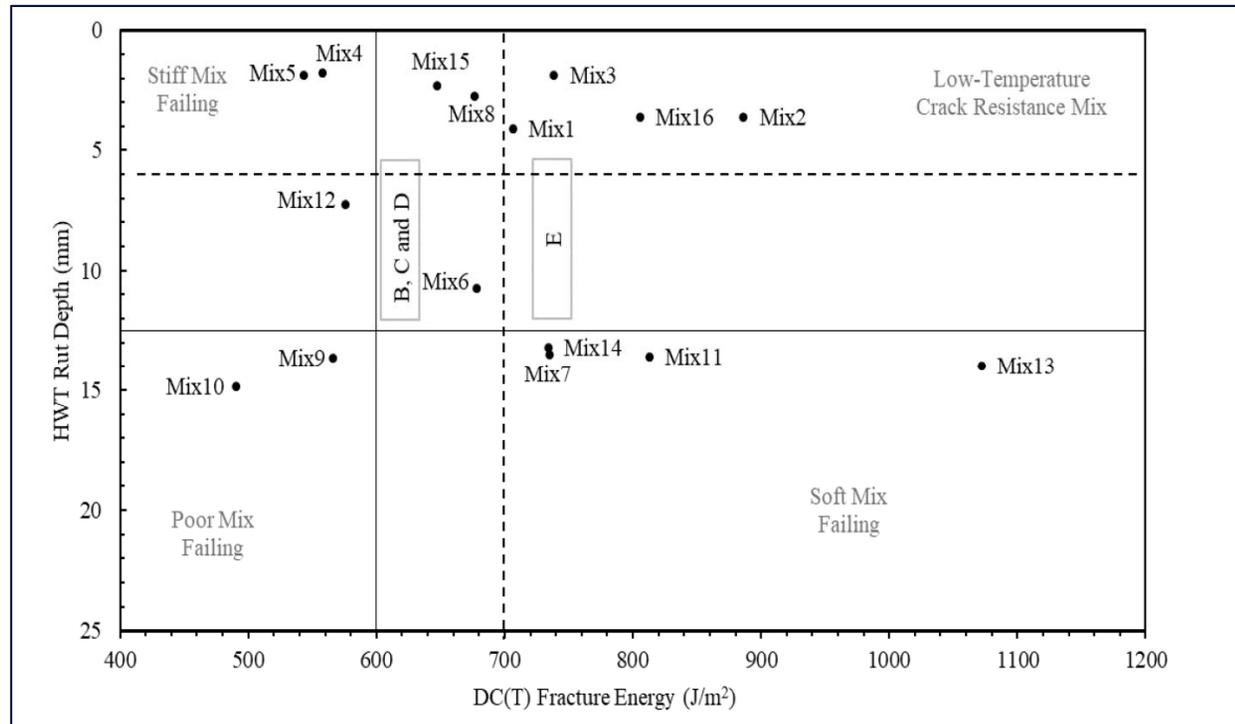
1	Recipe & Volumetric Selection	Presented in 2023
2	Performance-Verified Volumetric Design Verification of resistant to a specific distress Example: Asphalt Cement (AC) modification to resist fatigue cracking	
3	Performance-Modified Volumetric Design Adjustment of mix proportions to resist a specific distress Example: Mix Proportioning, PGAC Type, materials etc.	2025 Presentation
4	Performance-Based Design Durability Performance testing for Pavement design input Conduct Mix Volumetric Improvement	

TASKS 1 & 2

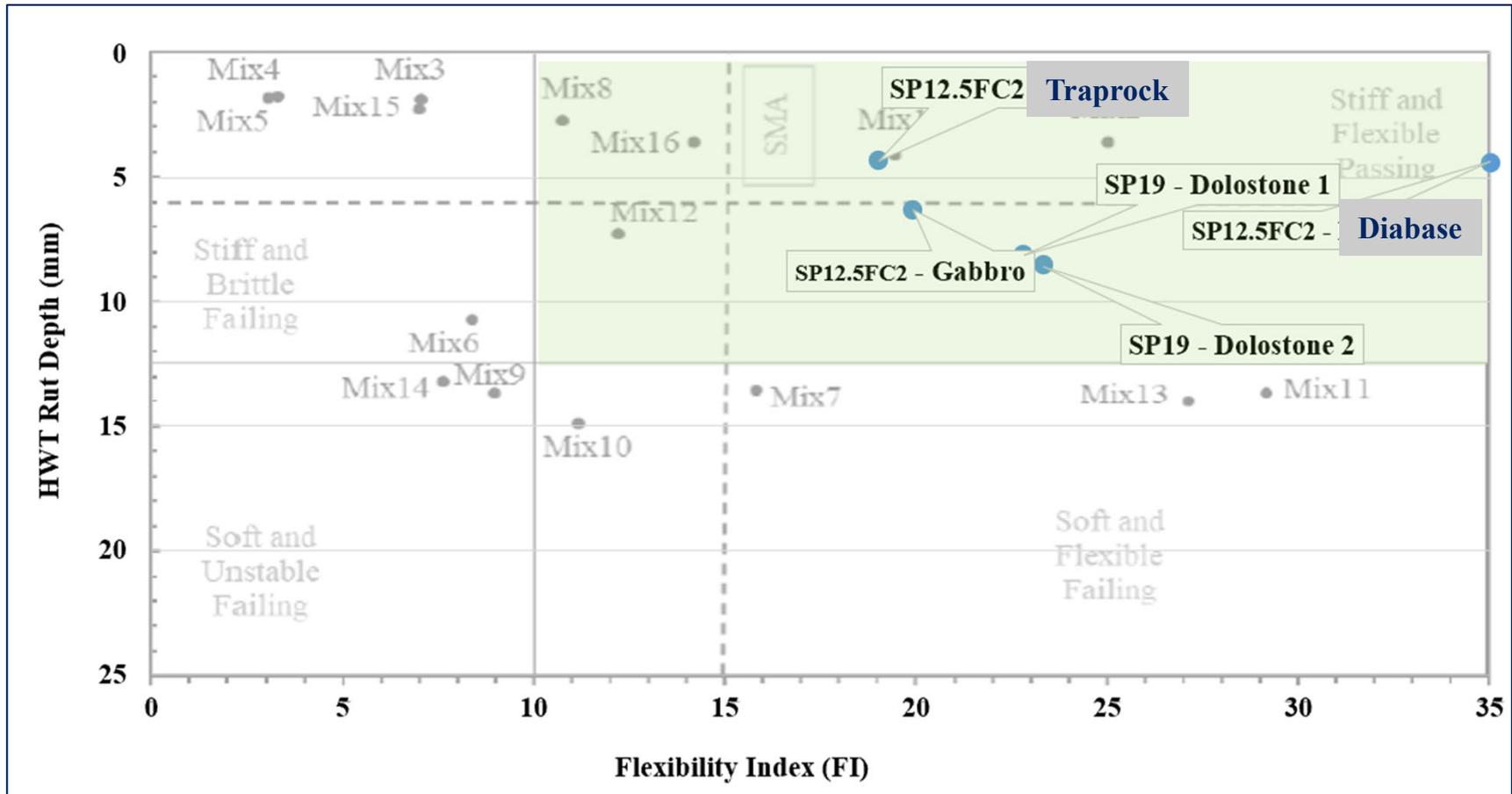
- EXPERIMENTAL WORK – SUMMARY OF FINDINGS
 - SuperPave Mix designs are Achievable
 - SuperPave Mixes can be designed with Optimal Performance Testing Indicators like:
 - Hamburg Rut Wheel Testier (Plastic Flow)
 - Semi-Circle Bend Test (Intermediate Temperature Fracture Mechanics Properties)
 - Disc Shaped Compact Tension Test (Low Temperature Fracture Mechanics Properties)
 - Certain Aggregate Mixes and PGAC Combinations Produce Best Performance Characteristics with Volumetric properties
 - Order -> Diabase then Gabro-> Trap Rock for Surface Course Mixes
 - Order -> Dolostones perform similar for base Course Mixes
 - Tasks 3 and 4 work are needed to complement the initial results obtained in Tasks 1 and 2.
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PERFORMANCE SPACE DIAGRAM (PSD)

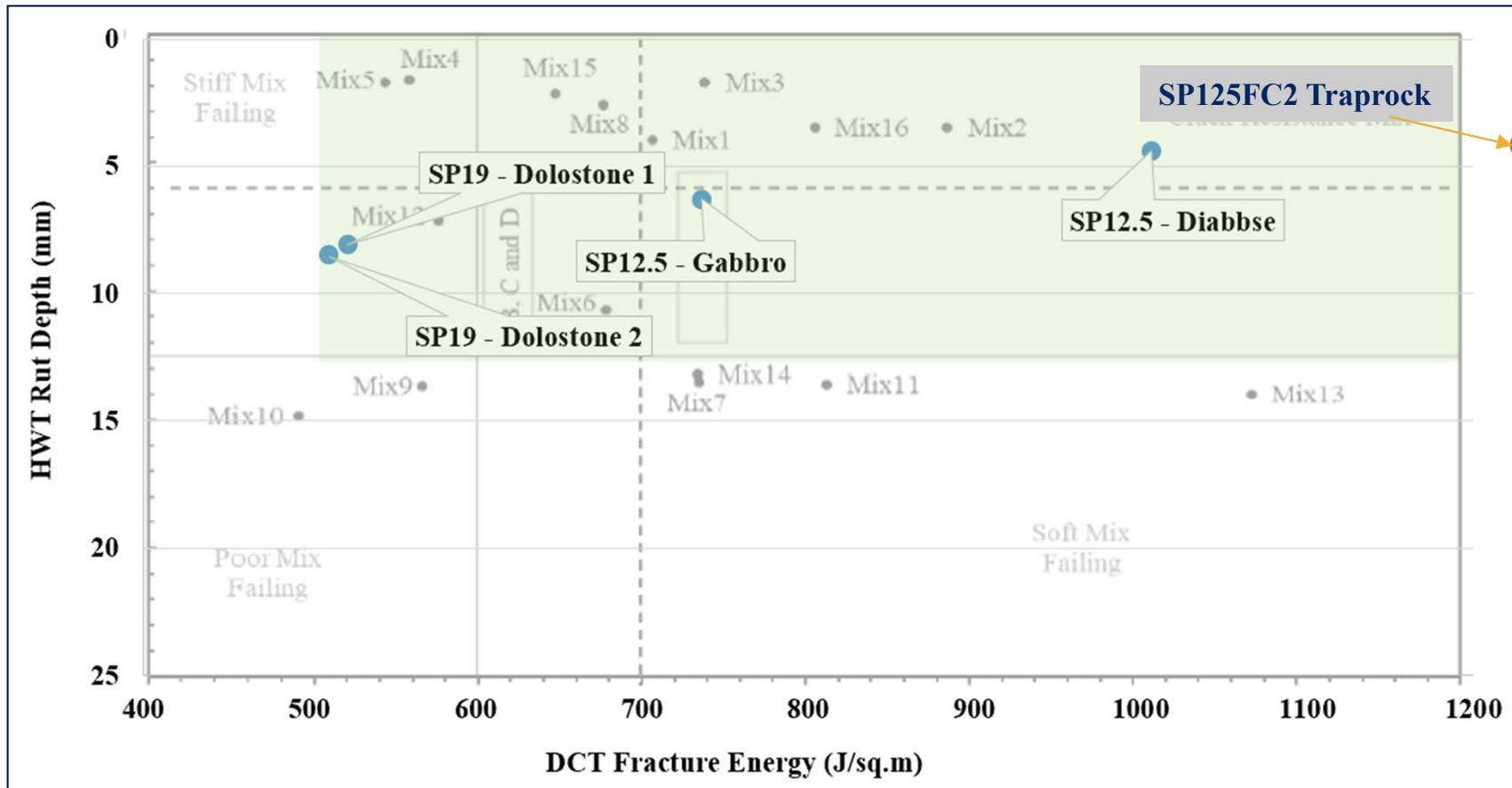
- PSD Example Developed by the Ministry of Transportation in Ontario, showing Rut Depth using the Hamburg Wheel Tracking (**HWT**) device versus low temperature cracking fracture energy using the Disk-Compact Tension Test (**DCT**).
- This PSD was used to evaluate GTAA mixes.



PERFORMANCE SPACE DIAGRAM (PSD) - 2023



PERFORMANCE SPACE DIAGRAM (PSD) - 2023



TASK 3 – BALANCING MIX DESIGNS

- EXPERIMENTAL WORK

- After Completion of Task 1 and Task 2, the Federal Highway Administration (FHWA) Balanced Mix Design (BMD) guidelines were used to evaluate mix performance(s) in terms of fatigue, durability, rutting resistance, and resistance to low-temperature cracking at various AC Contents.
 - This is to validate the mix designs and performance characteristics over a range of AC contents
 - For each mix, after achieving volumetric balance and benchmarking, the Asphalt content was adjusted within a range of +0.5% and -0.5% to establish what is referred to as a "**performance envelope**."
 - This evaluation of sensitivity will contribute to developing a model that could be integrated into contractual agreements.
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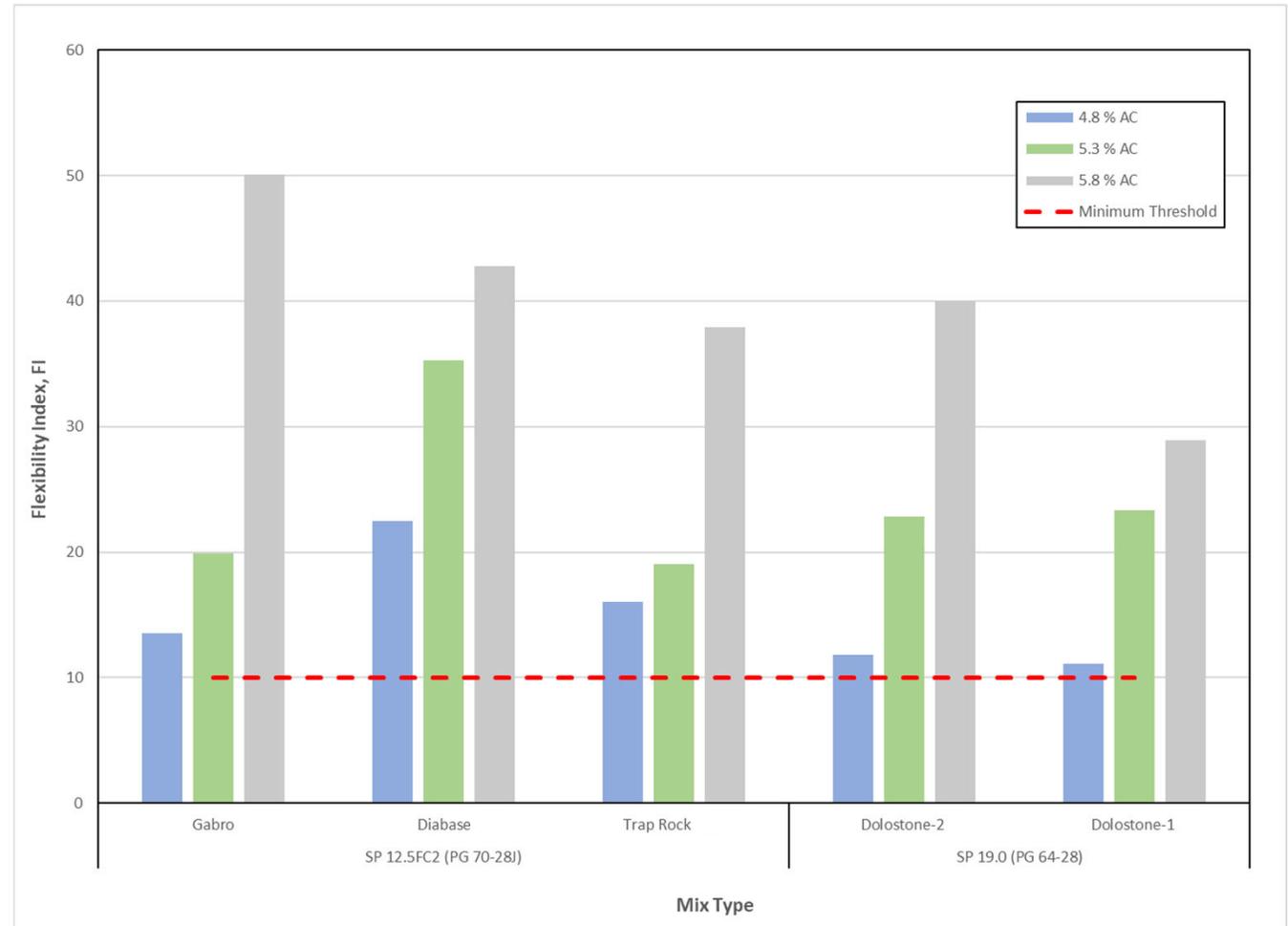
TASK 3 – BALANCING MIX DESIGNS

- Task 3 – Balancing Mix Designs

Mix Name	Surface Mix						Binder Mix			
Aggregate Type	Gabro		Diabase		Trap Rock		Dolostone-1		Dolostone-2	
Mix Type	SP12.5FC2		SP12.5FC2		SP12.5FC2		SP19.0		SP19.0	
Binder Type	PG 70-28 J		PG 70-28 J		PG 70-28 J		PG 64-28 J		PG 64-28 J	
Tested AC% Content	4.8	5.8	4.8	5.8	4.8	5.8	4.8	5.8	4.8	5.8

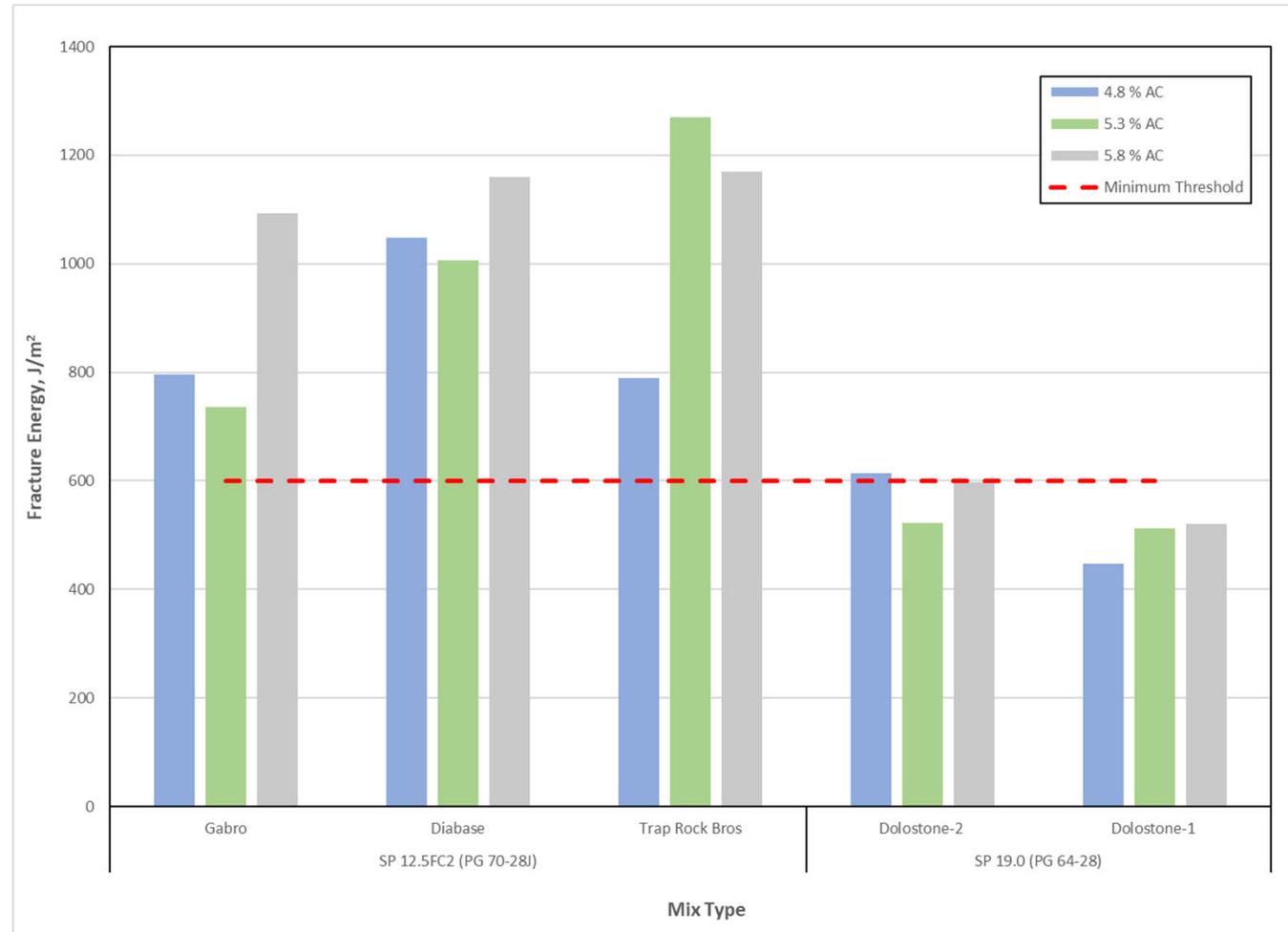
TASK 3 – Fatigue Crack Resistant – I-FIT (SCB) Test

- Diabase mix shows highest flexibility index at 5.3% AC
- Trap Rock mix shows lowest fatigue resistance
- Fatigue resistance improves with higher asphalt content
- Optimizing AC levels enhances crack resistance
- Balanced AC design increases pavement durability



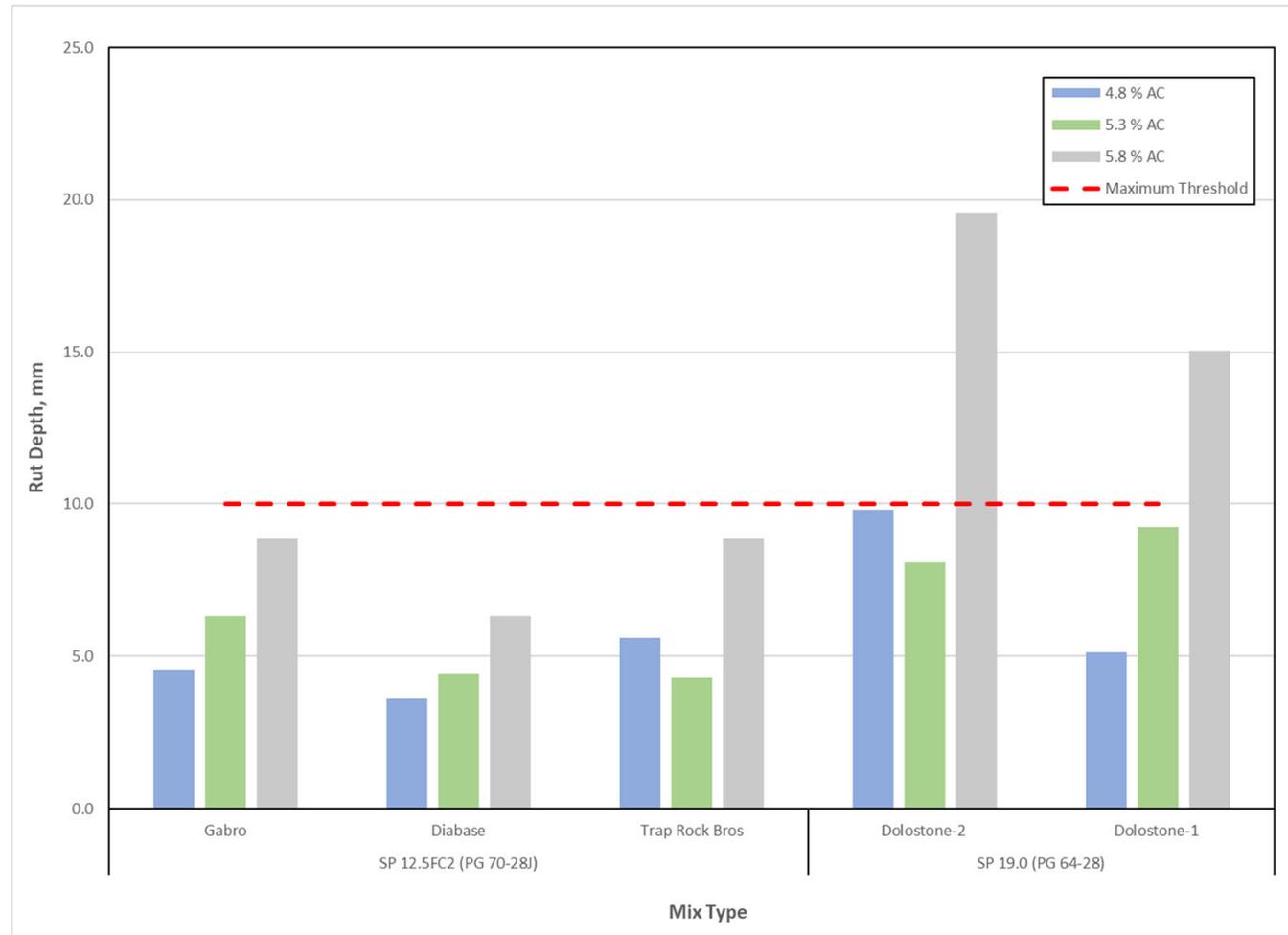
TASK 3 – Disk-Shaped Compact Tension (DCT) Test

- Surface mixes show excellent low-temperature crack resistance at all AC levels
- Strong durability and integrity in cold-weather conditions
- Binder mixes fail MTO's 600 J/m² fracture energy requirement
- Improvement needed in binder mix design



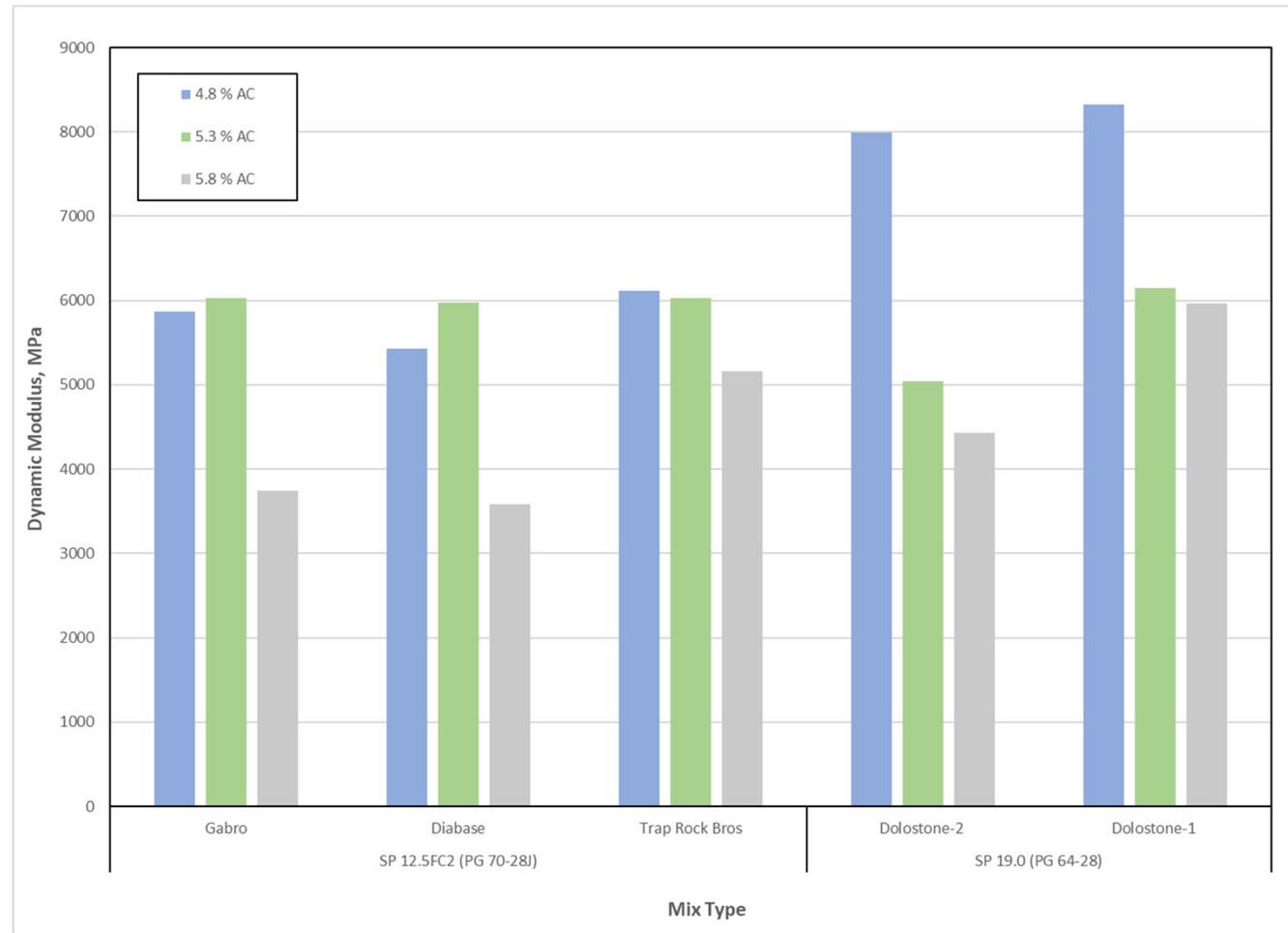
TASK 3 - Hamburg Wheel Tracking (HWT) Test

- Surface mixes show superior rut resistance at all AC levels (4.8%, 5.3%, 5.8%)
- Rut depths stay below MTO's 10 mm limit at 50°C / 20,000 passes
- Binder mixes meet criteria at 4.8% and 5.3% AC
- Binder mixes fail rut resistance at 5.8% AC
- Careful AC Content selection needed to balance rutting, flexibility, and crack resistance



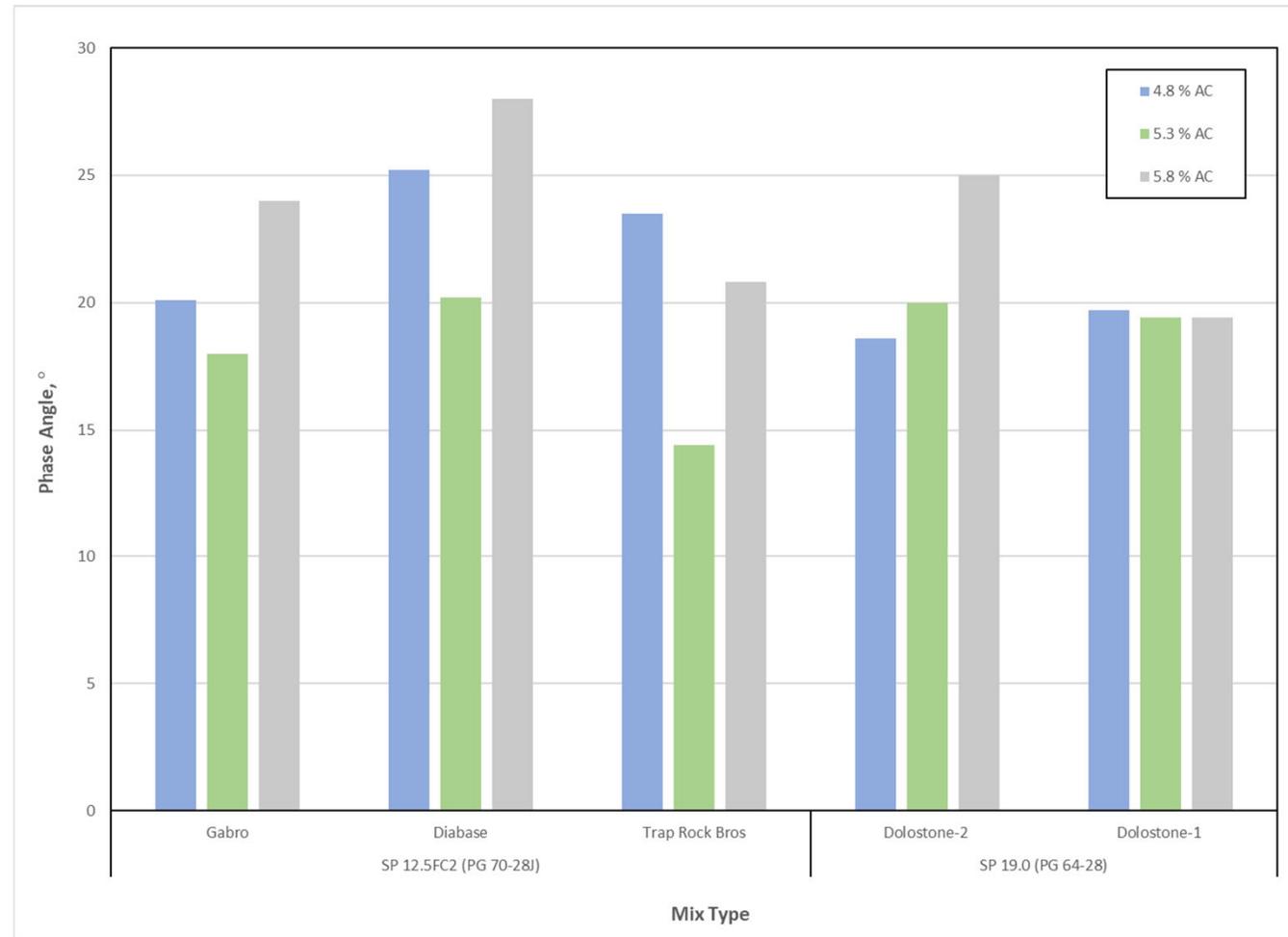
TASK 3 - Stiffness - Dynamic Modulus

- Mixes with 5.8% AC show reduced dynamic modulus (lower stiffness)
- Reduced stiffness = lower load resistance
- 5.3% AC mixes achieve best balance of stiffness and flexibility
- Highlights 5.3% AC as optimal for durability and longevity
- Dolostone-2 Base Mix deviates from trend likely due to material factors



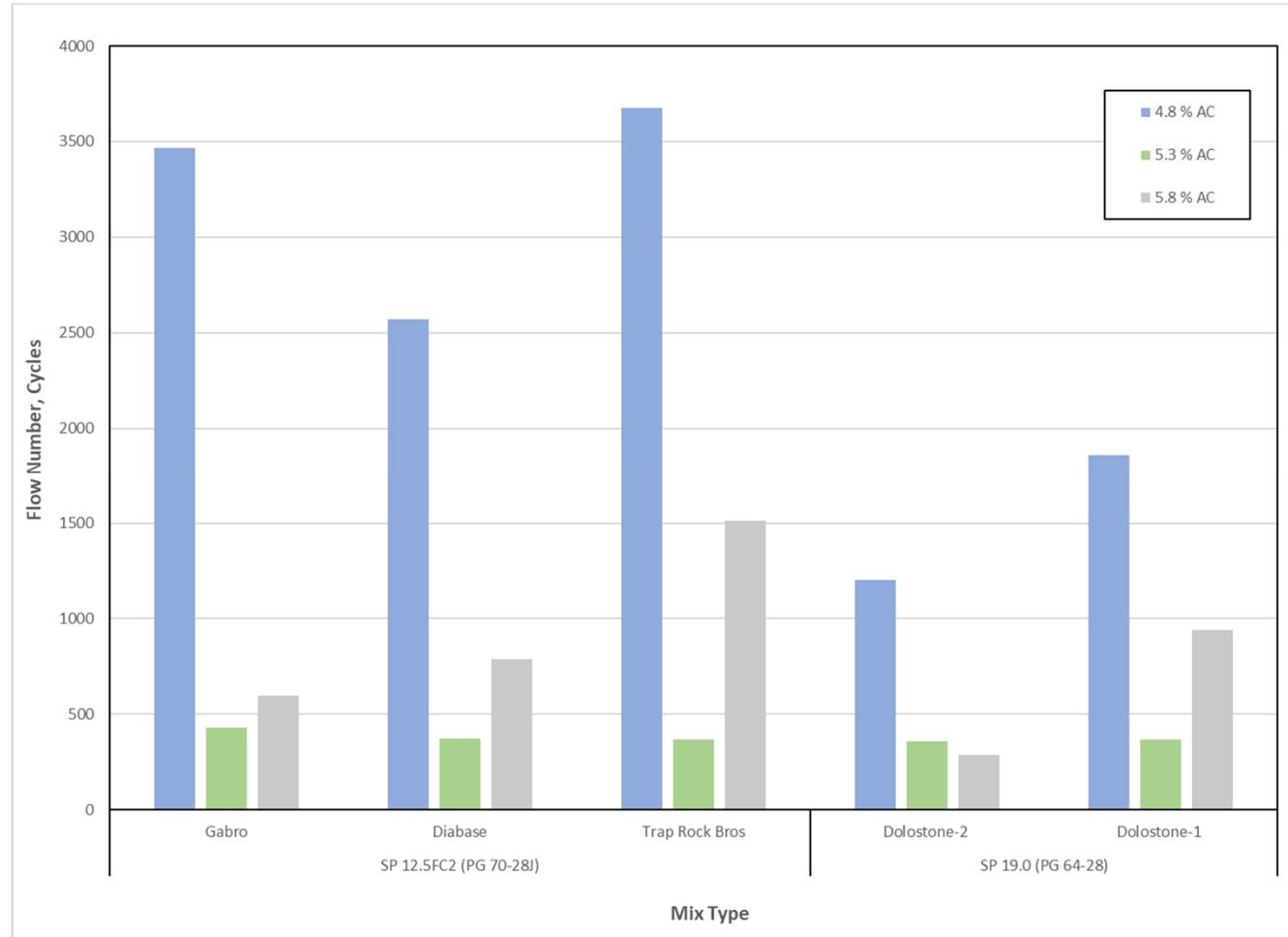
TASK 3 – Phase Angle

- Dolostone-1 mix shows consistent phase angles across AC levels
- 5.3% AC mixes display most elastic behavior (lowest phase angles)
- Lower phase angle = more elastic, less prone to deformation
- Optimizing AC content balances elasticity and viscoelasticity
- 5.3% AC identified as optimal for stable, durable pavement performance



TASK 3 – Flow Number

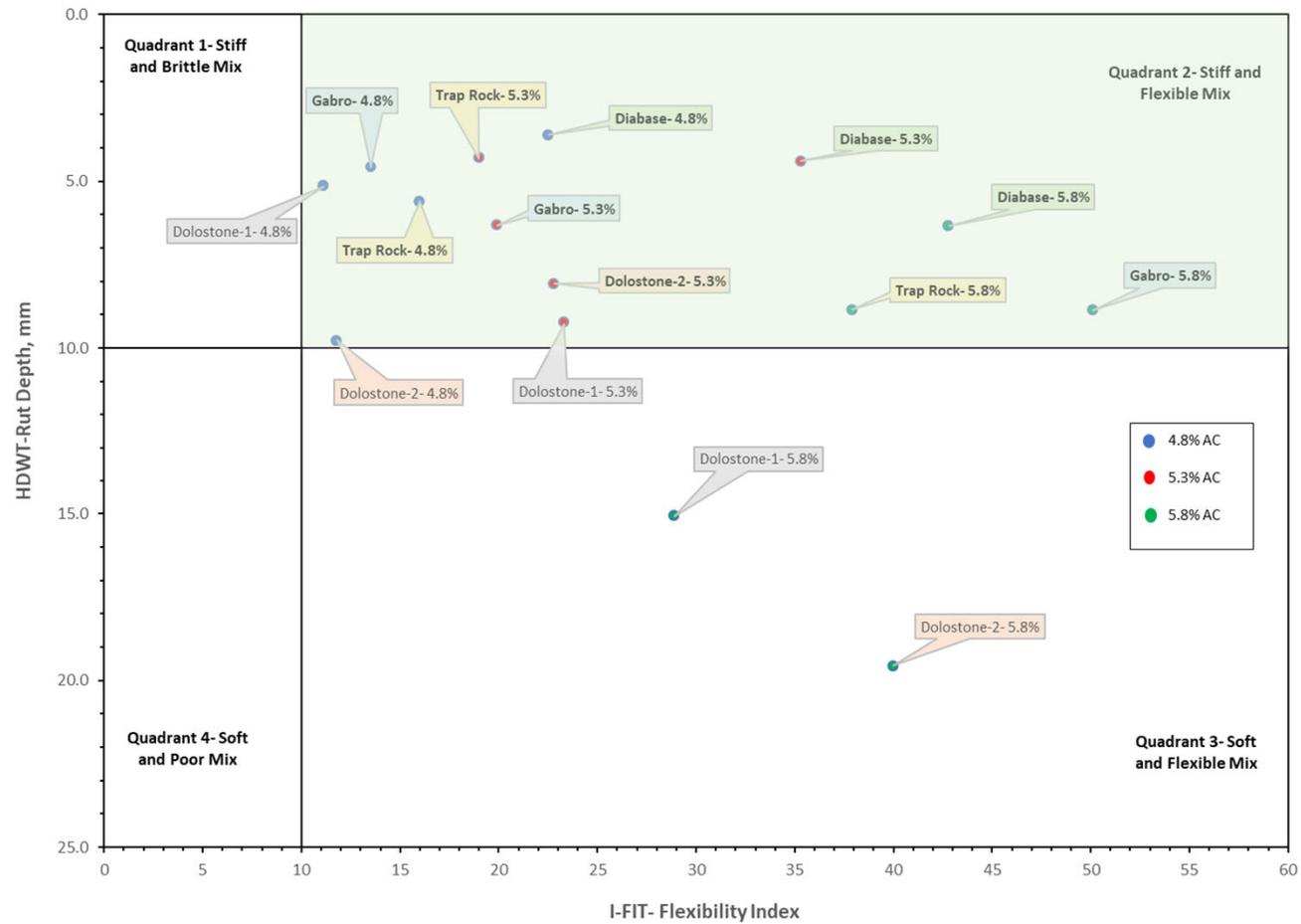
- Mixes with 4.8% AC show highest Flow Numbers (best rut resistance)
- 5.3% and 5.8% AC mixes have lower values but still meet AASHTO T378 Category C (≥ 50)
- All mixes suitable for moderate to high deformation resistance
- Careful AC selection balances durability and performance
- **HWT test preferred for rut resistance (more realistic traffic simulation)**



TASK 3 – COMMENTS ON TEST RESULTS

- The SCB/IFT Test Indicates Compliance to Intermediate Temperature Requirements for a Resiliency for all Mixes.
 - From a DCT perspective, all three surface mixes perform exceptionally well, whereas the two binder mixes exhibit a a lower level of resistance to low-temperature cracking.
 - From a Rutting perspective, the three surface mixes perform exceptionally well, whereas the two binder mixes exhibit a borderline week rut resistance.
 - From a Dynamic Modulus and Phase Angel perspective, the mixes formulated with 5.3% AC content stand out for their superior performance in meeting the established criterion.
 - From a Flow Number Perspective all the mixes show the Lowest Value for 5.3% AC, which is an odd behavior. Note that Hamburg is considered to be more reliable test in this area.
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TASK 3 – PSD DIAGRAM



TASK 3 – COMMENTS ON PSD DIAGRAMS

- All Surface Course Asphalt and Base Course Asphalt Mixes fall within the Quadrant 2 of the PSD Diagram indicating Stiff and Flexible Mixes (5.3% AC Content)
 - Higher AC Content Mixes that Fall in the Soft Zoner and are considered to be undesirable for Airport Projects addressing the Mechanical Loading Concerns.
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TASK 4 – EXTREME TEMPERATURE RESILIENCY

• EXPERIMENTAL WORK

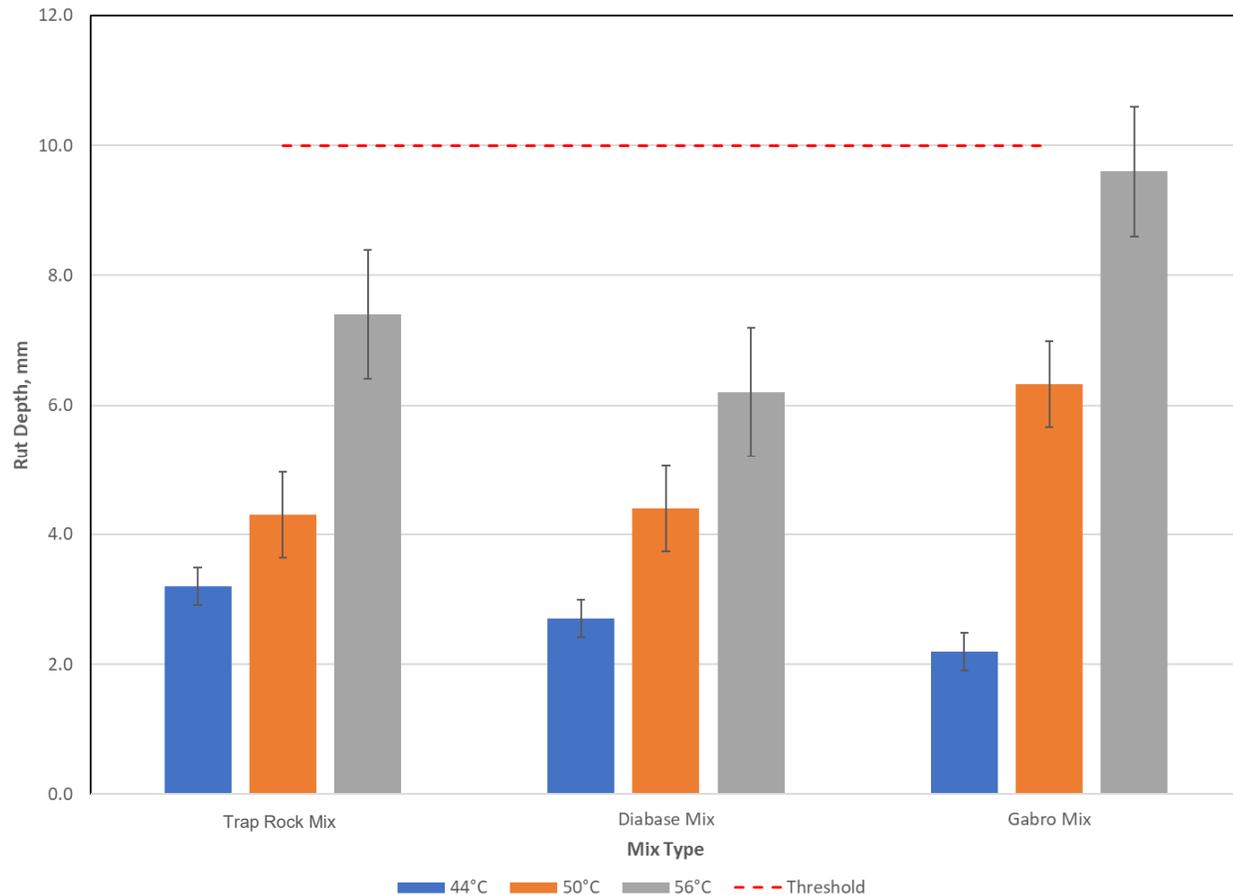
- Given these anticipated climate challenges, extreme event resiliency is a key consideration in the development of Balanced Mix Designs (BMDs) under Task 3.
 - In this context, "extreme events" refer to environmental conditions that significantly impact asphalt mix performance, exceeding the standard Performance Grade Asphalt Cement (PGAC) specifications recommended in previous tasks.
 - Among the pavement structure, the Surface Course is the most affected by climate fluctuations, as it is directly exposed to thermal, moisture, and mechanical loading effects.
 - Conversely, base asphalt layers are expected to remain relatively stable. As such, Task 4 focused on evaluating the resiliency of surface course asphalt mixes that were pre-selected based on Task 3 findings.
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TASK 4 – EXTREME TEMPERATURE RESILIENCY

- In recent year, the surface temperature sensors at Pearson indicated that the hottest pavement surface temperature was recorded at 64°C
 - The following three laboratory tests were conducted on the selected surface course mixes:
 - Hamburg Wheel Tracking (HWT) Test
 - Evaluates rutting resistance and moisture susceptibility of asphalt mixes.
 - Tests were conducted at 44°C and 56°C (compared to 50°C in Task 3).
 - Semi-Circular Bend (SCB) Test
 - Measures intermediate-temperature cracking resistance (fatigue cracking performance).
 - Tests were conducted at 5°C and 15°C (compared to 25°C in Task 3).
 - Disk-Shaped Compact Tension (DCT) Test
 - Assesses low-temperature cracking resistance (thermal cracking behavior).
 - Tests were conducted at -24°C and -30°C (compared to -18°C in Task 3).
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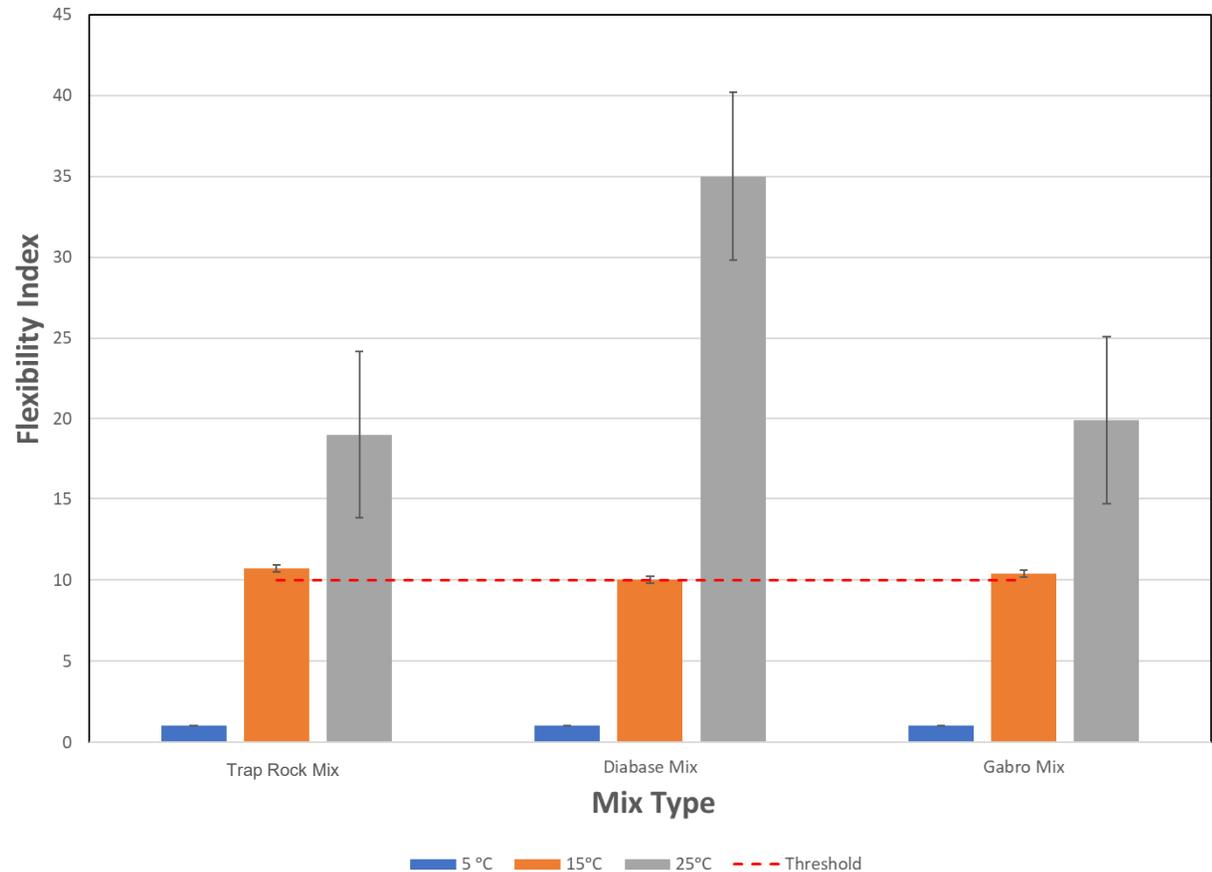
TASK 4 – Hamburg Wheel Tracking (HWT) Test

- Gabro mix, when considering standard deviation, approaches the 10 mm rut depth threshold at 56°C. This suggests that at extreme temperatures, plastic flow does become a concern.
- Increasing the PG grade from PG 70-28J to **PG 76-28J** would provide additional rut resistance and long-term durability in extreme conditions.



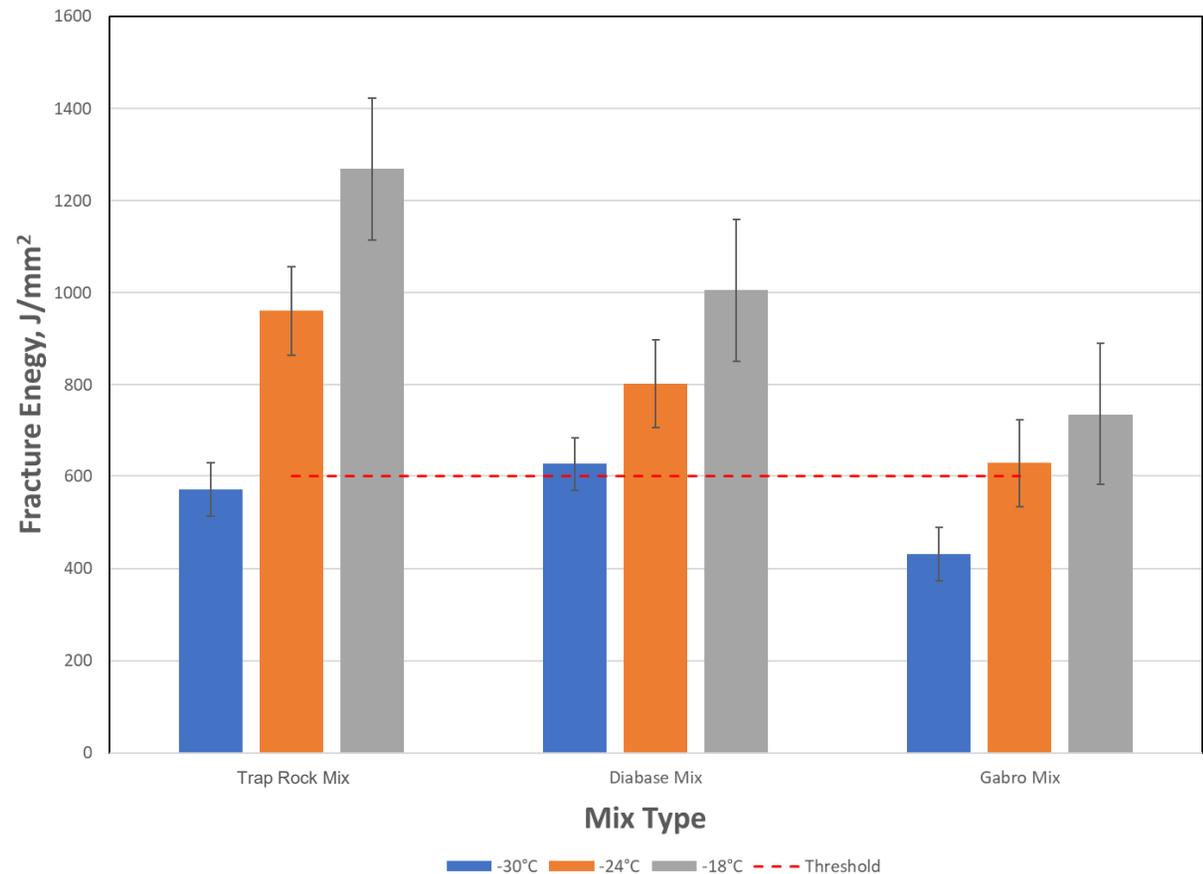
TASK 4 – Semi-Circular Bend Test (SCB)

- To account for the effects of global warming, it is anticipated that raising the intermediate test temperature will improve the SCB value.
- Even under the isolated circumstance in which the intermediate temperature falls to 15°C, the SCB test still meets the minimum threshold of 10.
- In addition, switching the PGAC grade to PG 76-28J is expected to further improve the SCB test value.



TASK 4 – Disk-Shaped Compact Tension (DCT) Test

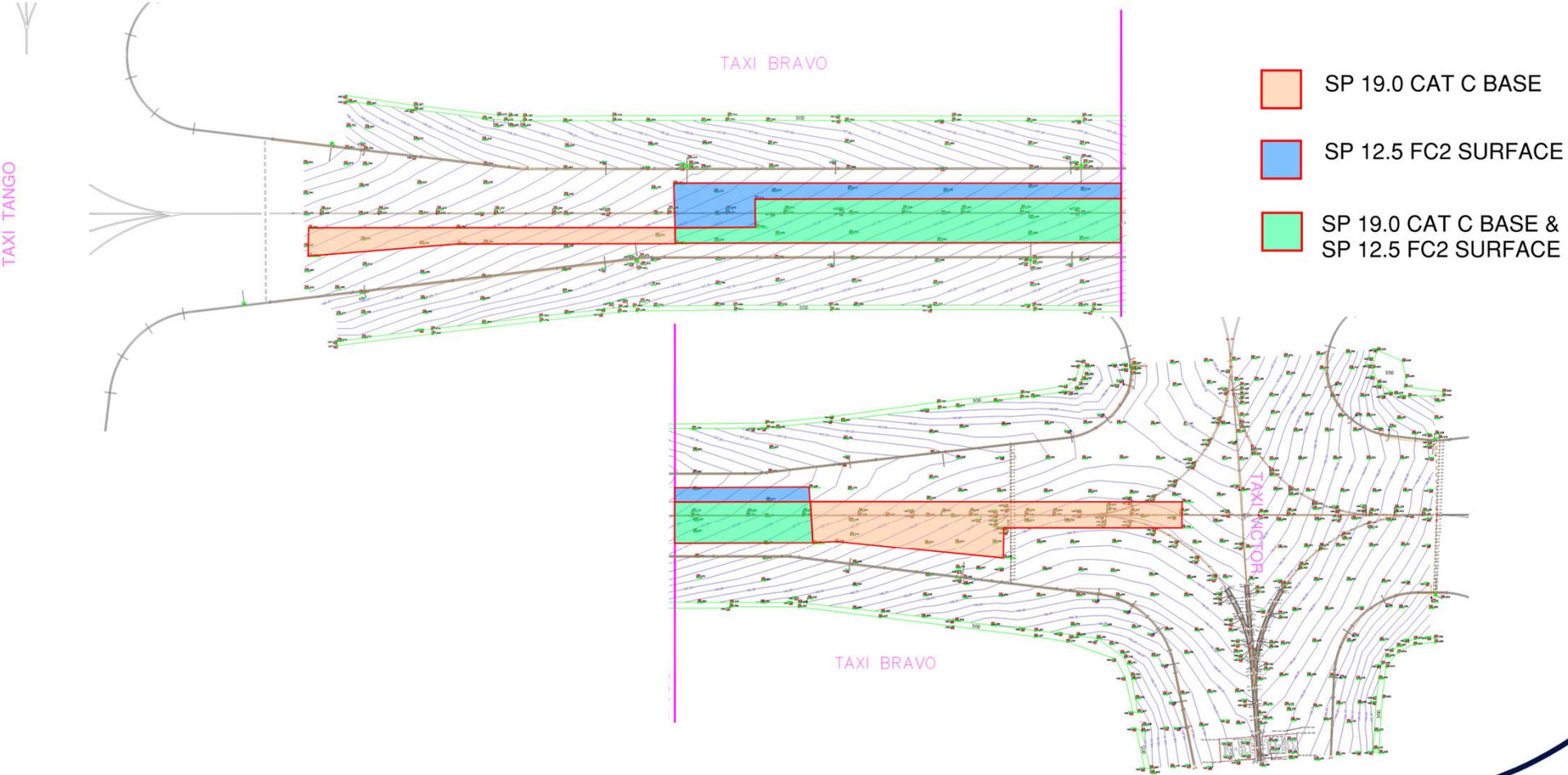
- While the Trap Rock and Diabase mixes performed well above this threshold, the Gabro mix fell below the minimum requirement. This underperformance at -24°C raises concerns.
- It is recommended to:
 - Modify the Gabro mix design by incorporating higher polymer-modified PGAC (i.e. as an example PG 76-28J)
 - Prioritize DCT results at -24°C for extreme resiliency assessment, as -30°C represents an unlikely scenario for Toronto.



FIELD TRIALS

- 3 trials were done in fall 2023 on Bravo Taxiway plus Control Section,
 - **Trial 1 in Beige Colour:** Volumetric Lower Course with Regular Surface Course, approx. 250M.T.
 - **Trial 2 in Green Colour:** Volumetric Lower Course with Volumetric Surface Course together, approx. 250M.T.
 - **Trial 3 in Blue Colour:** Regular Lower Course with Volumetric Surface Course, approx. 250M.T.
 - **Control Section in White Colour:** Regular Lower Course and Surface Course
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FIELD TRIALS



FIELD TRIAL PHOTOS – 2 YEARS POST CONSTRUCTION



CONCLUSION

- Analysis confirms asphalt mixes meet performance standards. Testing shows strong rutting, fatigue, and thermal cracking resistance.
 - GTAA mixes are balanced and viable. Performance Space Diagrams validate their long-term use.
 - HWT, DCT, and SCB tests show limits under extreme heat and heavy aircraft loads. Performance remains acceptable under normal conditions.
 - Climate change and traffic demand stronger binders. Current PG 70-28J is no longer sufficient for the critical area.
 - Upgrade to PG 76-28J. Higher polymer content improves rutting and cracking resistance.
 - This enhanced binder is expected to bolster the SCB, DCT, and Hamburg test performance, thus providing a more resilient, long-lasting pavement solution capable of meeting current and future operational requirements.
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Remarks and Questions

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Thank you

