Development of High Stability and Fuel Resistant Airfield Asphalt Mixture

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Fall Asphalt Seminar
December 1, 2022
Vaughan, Ontario

ACKNOWLEDGMENT

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Fermar Paving Limited

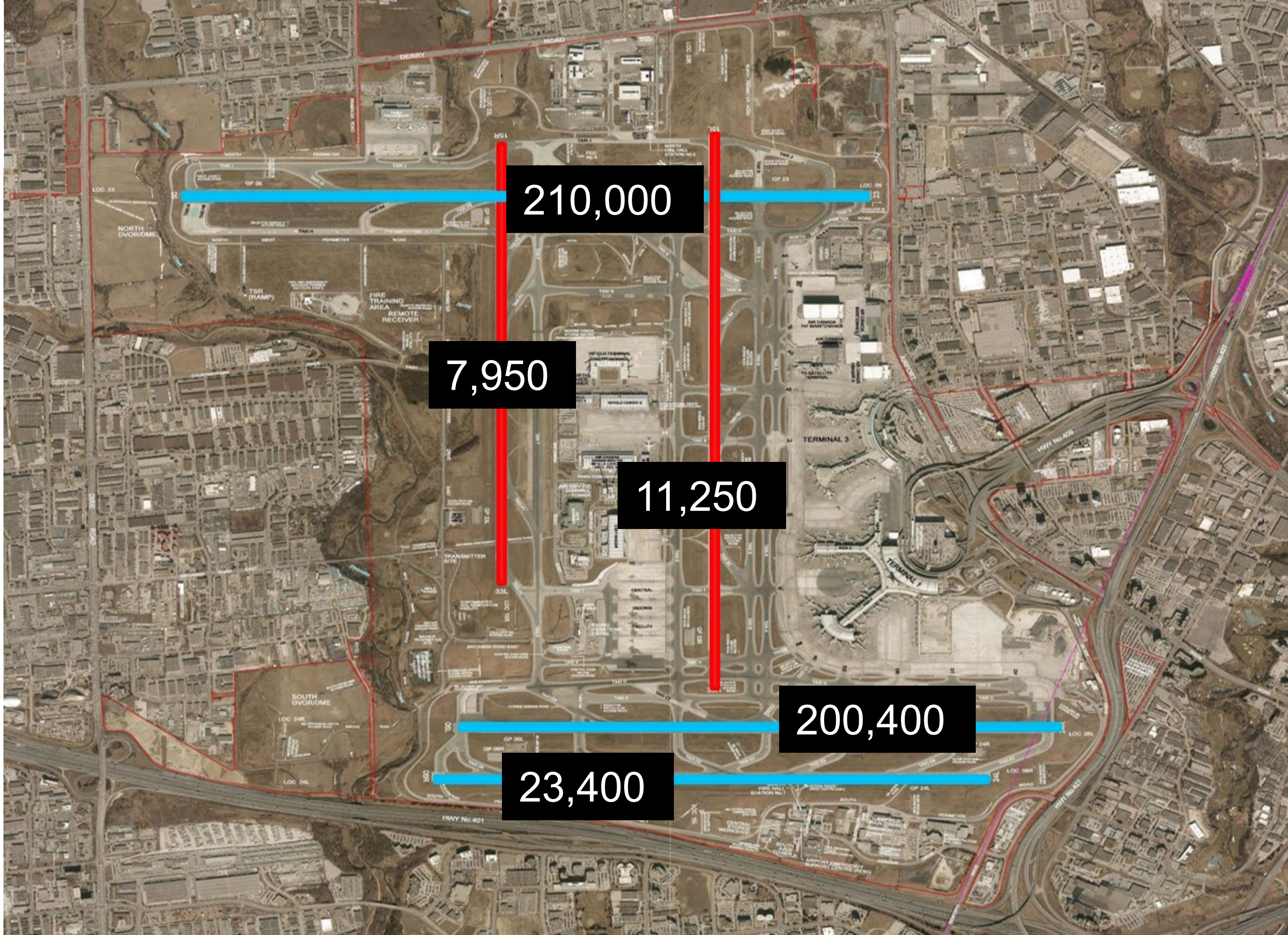
Dufferin Construction Company/CRH Canada Group

OUTLINE

- Asphalt Mix Challenges at The Pearson Airport
- Need for High Performance and Fuel Resistant Airfield Asphalt Mixtures
- Experimental Work on High Stability and Fuel Resistant Mix
- First in Canada Field Trials at the Pearson Airport
- Final Remarks

Toronto Pearson
International Airport | Aéroport International

2019 TRAFFIC MOVEMENT



TORONTO PEARSON CANADA'S LARGEST AIRPORT

• 2019 Passenger Volume	50.5 Million PAX.
• Ranking in North America*	2nd busiest airport
• Total airside paved areas (concrete and asphalt)	approx. 5.8 million m^2
• # aircraft movements:	approx. 453,000 annually
• Cargo processed:	513,000 tones
• Direct Jobs created:	51,000
• GDP contribution to Ontario	$42 Billion

In terms of international passengers, 32.4 Million PAX.

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 leading to unusual severe hot weather in the summer.
- Maintaining the integrity and safety of the airport’s daily operation is a must for all travelers and stakeholders.

ASPHALT MIX CHALLENGES AT GTAA

GTAA's Proactive Approach:

- Innovative opportunities such as Jet Fuel Resistant mix, fiber and wax additive, warm mix asphalt technology, dual layer asphalt paving equipment, perpetual pavement design, etc. to improve mix design to provide durable pavement and to minimize operational impacts due to planned/unplanned shutdown.
- Using premium materials for better durability and frictional properties.
- More collaboration with contractors, suppliers and experts in 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.
- More collaboration with other airports and universities (i.e., Canadian Airfield Pavement Technical Group (CAPTG) and University of Waterloo Centre for Pavement and Transportation Technology (CPATT)).

ASPHALT MIX CHALLENGES AT GTAA

Slippage of asphalt away from the inset light

Pavement shoved at the hold line position

ASPHALT MIX CHALLENGES AT GTAA cont'd

Asphalt Sliding between layers due to braking and turning

Shoving in asphalt due to heavy braking of fully loaded aircraft

STUDY OBJECTIVES

- Collaborative work between GTAA, SNC-Lavalin, and McAsphalt Industries
- Development of FAA P-404 Airfield Asphalt Mixture using locally available premium materials
- Completion of a field trial
- 5-year field monitoring

USA FAA AC 150/5370-10H Item P-404 Fuel-Resistant Asphalt Mix Pavement

Table 1. Marshall Design Criteria

Test Properties	All Aircraft	Test Method
Number of blows	50	ASTM D6926
Stability, minimum	2150 lbs.	ASTM D6927
Air Voids[1]	2.5 ±0.2 %	ASTM D3203
Minimum voids in mineral aggregate (VMA)	14%	ASTM D6995
Maximum weight loss by fuel immersion	1.5%	in accordance with procedures outlined in paragraph 404-3.4
Tensile Strength Ratio (TSR)[2]	not less than 80 at a saturation of 70-80%	ASTM D4867
Asphalt Pavement Analyzer (APA)[3]	Less than 10 mm @ 4000 passes	AASHTO T340 at 250 psi hose pressure at 64°C test temperature

1 If the water absorption of the combined aggregates in the mix exceeds 1.7% (ASTM C127 and ASTM C128) then the mix must be short term aged in accordance with American Association of State Highway and Transportation Officials (AASHTO) PP-2 – Section 7.2. The short term aged material will then be used for the Marshall specimens and the maximum specific gravity test (ASTM D2041).

2 Test specimens for TSR shall be compacted at 7 ± 1.0 % air voids. Use freeze-thaw conditioning in lieu of moisture conditioning per ASTM D4867.

3 AASHTO T340 at 100 psi hose pressure at 64°C test temperature may be used in the interim. If this method is used the required value shall be less than 5 mm @ 8000 passes.

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The APA procedure has shown that mixes that meet the requirements above perform well under aircraft loading. The APA is preferred on airport pavement projects serving aircraft greater than 60,000 pounds. If APA is not available in an area, compacted mix design samples may be sent to a laboratory that has an APA or the Hamburg wheel test (AASHTO T 324) 10mm @ 20,000 passes may be used with FAA approval.

GTAA P-404 MIXES MATERIALS

	Sieve Size (mm)	Trap Rock	Diabase	Gabbro	P-404 Specification
Gradation % Passing	16	100	100	100	100
	12.5	99.2	98.5	99	100
	9.5	93	91.2	91.2	90 – 100
	4.75	61.1	61.3	62.4	58 – 78
	2.36	41.1	50.1	42.8	40 – 60
	1.18	32.3	32.5	28.1	28 – 48
	0.6	25.2	20.5	18.9	18 – 28
	0.3	11.8	12.4	12.2	11 – 27
	0.15	7.5	7.3	6.6	6 – 18
	0.075	6	4.5	3.6	3 – 6

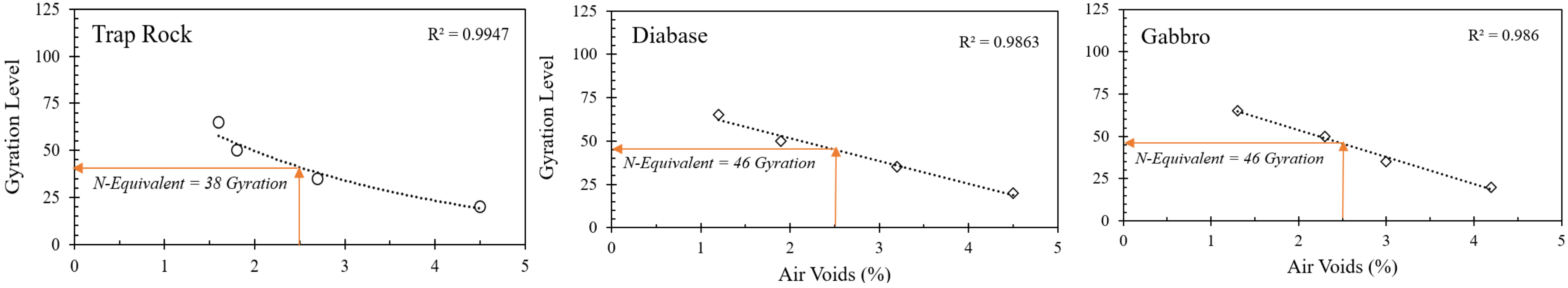
NOTES:

1. *P-404 is Federal Aviation Administration (FAA) Specification, under AC 150/5370-10H Section: 404-2.1*
2. *The binder was formulated to also ensure P-404 Section 404-2.3 (meeting ASTM D6373 for performance grade PG 82-28FR)*

EXPERIMENTAL MATERIALS

Properties	Trap Rock	Diabase	Gabbro	P-404 Specification
Binder Content, %	6.9	6.9	6.5	5.5 – 8.0
Design Air Voids, %	2.5	2.5	2.5	2.5
Design VMA, %	18.6	19.4	18.2	14%
Stability, N	14,289	15,543	14,127	9,564
Flow (0.25 mm)	26.0	23.0	19.0	
Bulk Relative Density (Gmb)	2.515	2.515	2.532	
Maximum Specific Gravity (Gmm)	2.579	2.580	2.595	
Asphalt Film Thickness (AFT), µm	13.2	15.7	16.3	
Tensile Strength Ratio (TSR), %	92.7	97.6	90.6	Minimum 80

N-equivalency (Superpave Gyratory Vs. Marshall)



ASSESSMENT OF MIXTURES PERFORMANCE

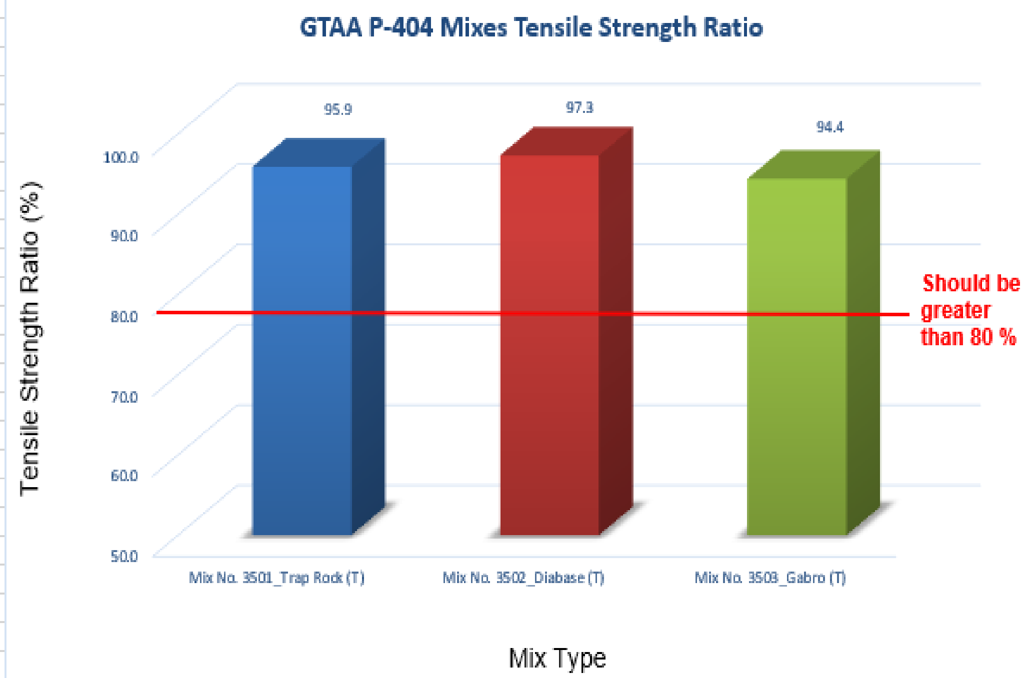
Distress Target	Test
Fuel Damage	Fuel Immersion Test
Moisture-Induced Damage	AASHTO T283 Tensile Strength Ratio
Overall Stiffness	AMPT – Dynamic Modulus
Fatigue Cracking	Semi-Circular Bending (SCB)
Rutting/Shoving	AMPT –Flow Number
	Asphalt Pavement Analyzer (APA)
	Hamburg Wheel Tracking Device

FUEL-IMMERSION TEST

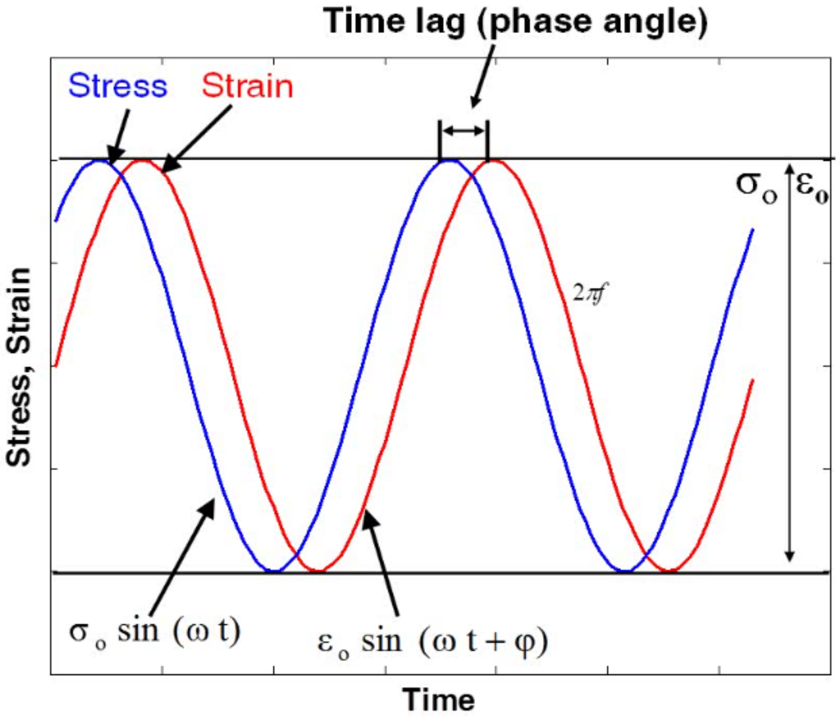
- P-401 specifications required compacted mix samples to be immersed in jet fuel for 24 hours
- Standard Hot Mix Asphalt mixture loses 10% weight from 24-hour soak in jet fuel

Mix Name	Design Method	% Mass Loss After 24 hour Immersion	FAA P-404 Requirement
Trap Rock	Marshall 50 blows	0.27%	1.5% maximum weight loss after fuel immersion
Diabase		0.16%	
Gabbro		0.14%	
Trap Rock	Superpave	0.14%	
Diabase		0.11%	
Gabbro		0.12%	

TENSILE TRENGHT RATIO (TSR)



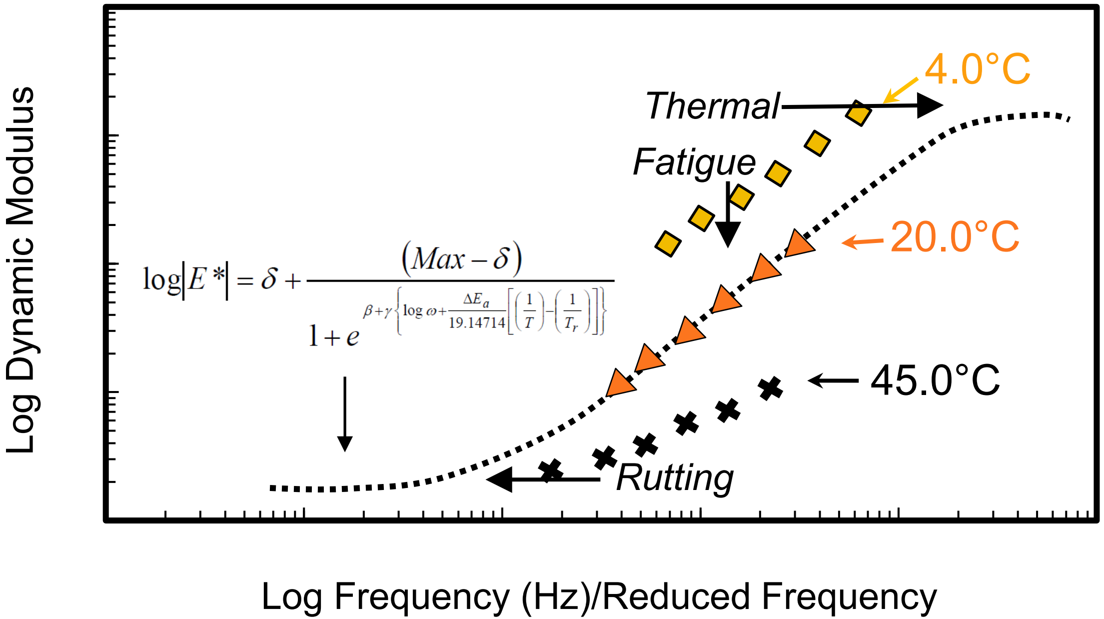
AMPT DYNAMIC MODULUS TEST



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

AASHTO Designation: T 378, Standard Method of Test for Determining Dynamic Modulus and Flow Number for Asphalt Mixture Using the Asphalt Mixture Performance Tester (AMPT)

DYNAMIC MODULUS AND MASTER-CURVES



Temp. (°C)	Freq. (Hz)
4.0 (Low Temp Cracking)	0.01 (Very Slow)
20.0 (Fatigue Cracking)	0.10
45.0 (Rutting)	0.50
	1.0
	5.0
	10.0 (Moderate)
	25.0 (High Speed)

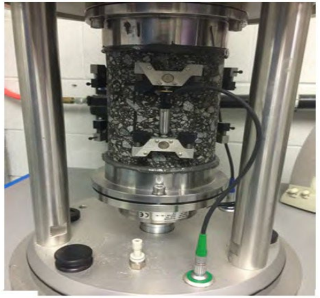
AASHTO Designation: R 84, Standard Practice for Developing Dynamic Modulus Master Curves for Asphalt Mixtures Using the Asphalt Mixture Performance Tester (AMPT)

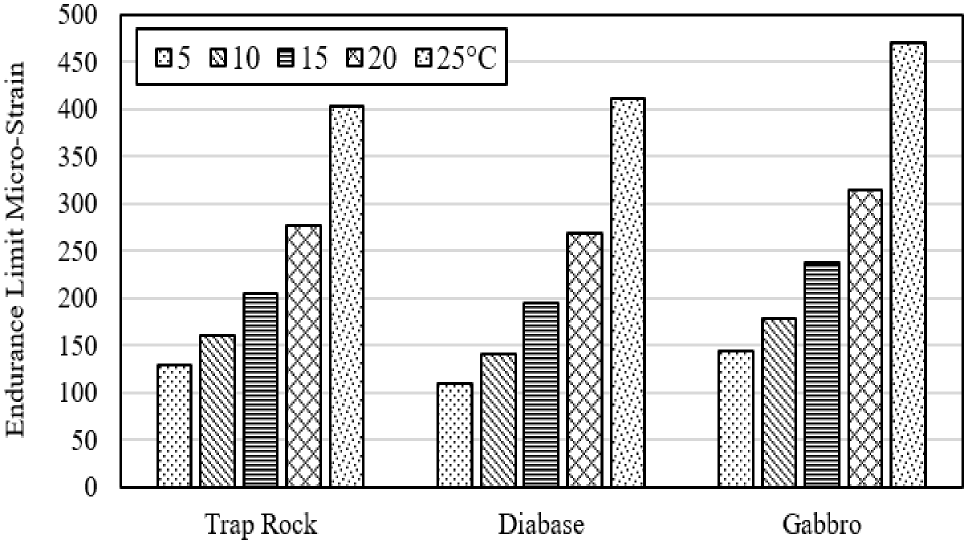
OVERALL STIFFNESS – DYNAMIC MODULUS

- **Notes:** Stiffness value was predicted for the conditions of 20°C using a frequency of 10 Hz.

Mix Name	Dynamic Modulus, E*, ksi at 10 Hz			Phase Angle (Degrees)		
	Testing Temperature, ºC			Testing Temperature, ºC		
	4ºC	20ºC	40ºC	4ºC	20ºC	40ºC
Trap Rock	1066.4	433.9	56.9	15.4	24.1	34.8
Diabase	1170.7	372.3	58.9	17.5	28.3	34.5
Gabbro	987.5	321.5	52.5	18.0	28.8	33.9

FATIGUE BEHAVIOUR UNDER DIRECT TENSION CYCLIC FATIGUE TESTS





AASHTO Designation: TP 107, Standard *Method of Test for Characteristic Curve and Failure Criterion Using the Asphalt Mixture Performance Tester (AMPT) Cyclic Fatigue Test.*

THE RUTTING AND MOISTURE-SUSCEPTIBILITY OF ASPHALT MIXTURES

- APA Rutting – AASHTO T340
  - PG 82-28 FR
  - 64°C test temperature
  - 100 lb. wheel load
  - 100 psi tire pressure
  - 8,000 cycles

- HWT – Testing – AASHTO T324
  - PG 82-28 FR
  - 705 N (158 lb.) load hard-rubber wheel
  - A total of 20,000-wheelpasses
  - 64°C test temperature

- Flow Number – AASHTO T 378
  - PG 82-28 FR
  - Testing temperature 43.9°C
  - 7.0 ± 0.5 % air voids
  - The short-term conditioning
  - Repeated deviatoric stress of 600 kPa

FLOW NUMBER (FN) – RESISTANCE OF ASPHALT MIXTURES TO PERMANENT DEFORMATION

Mix Name	Franken Model Curve Flow Number
Trap Rock	7,929
Diabase	2,990
Gabbro	3,448

Mix Name	Flow Number Micro-strain
Trap Rock	30,117
Diabase	35,589
Gabbro	28,702

Traffic Level - Million ESAL's	HMA Minimum Average Flow Number	WMA Minimum Average Flow Number
B / 0.3 to 3	-	-
C / 3 to 10	50	30
D / 10 to 30	190	105
E / ≥ 30	740	415

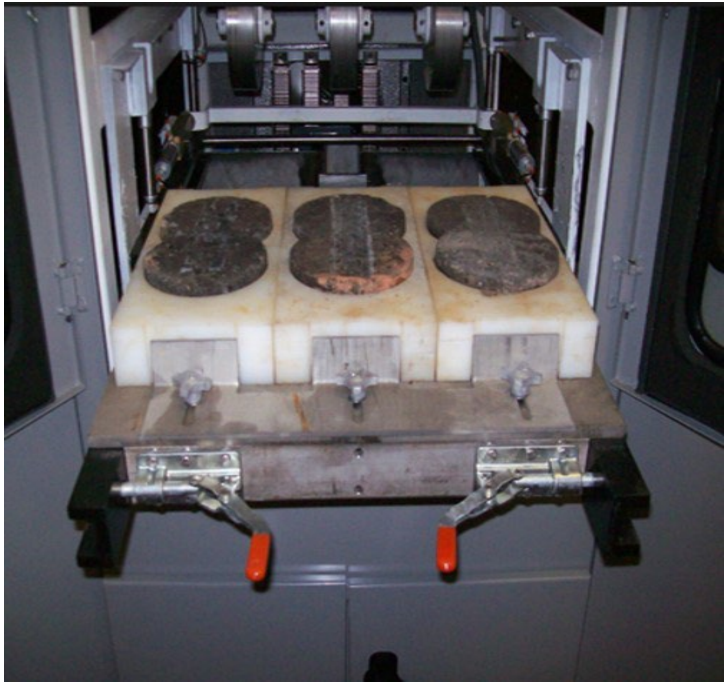
AASHTO T 378- 22, Table X2-4, Minimum Average Flow Number Requirements

RUTTING AND MOISTURE-SUSCEPTIBILITY OF ASPHALT MIXTURE - APA & HWT

Mix Name	Average APA Rut Depth (mm)	FAA P-404 Requirement
Trap Rock	2.57	Less than 5 mm at 8,000 passes
Diabase	2.59	
Gabbro	2.55	

Mix Name	Average Hamburg Rut Depth (mm)	FAA P-404 Requirement
Trap Rock	1.86	Less than 10 mm at 20,000 passes
Diabase	2.05	
Gabbro	1.92	

APA Testing - National Centre for Asphalt Technology (NCAT) at Auburn University, Auburn, United States.



Hamburg Wheel-Track Testing of designed GTAA P-404 mixes was directed by Centre for Pavement and Transportation Technology (CPATT), University of Waterloo.

FURTHER GTAA PERFORMANCE TESTS ON P-404 PLANT PRODUCED MIXES

Disc-Shaped Compact Tension Test (ASTM D7313):

Illinois Flexibility Index Test (T 393)

Asphalt Mixtures Performance Tester (AMPT) Tests

Hamburg Wheel-Tracking Test (T 324)

Asphalt Pavement Analyzer (T 340):

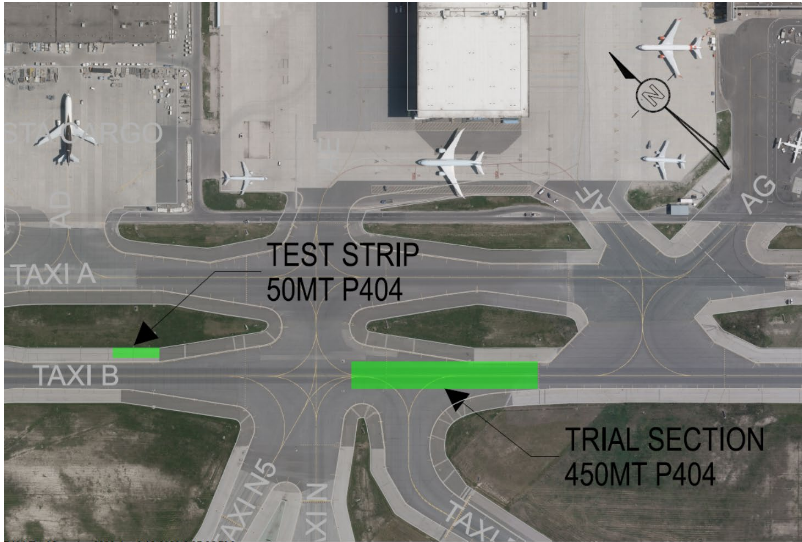
PLANT PRODUCTION AND PAVING EXPERIENCE

» Production

- Located approximately 15 km from the Airport
- Mix produced at 165 ± 5°C using a drum plant
- No issues mixing the binder with aggregate blend to achieve proper coating

» Test Strip paved on October 13, 2020 (50MT) on Taxiway Bravo

- Establishing rolling patterns
- Allowing production & paving crew gain experience with the mix



PAVING 50MT TEST STRIP (OCTOBER 13, 2020)

- Intended to be paved in echelon
- Technical issues with one paver – switched to one-lane paving

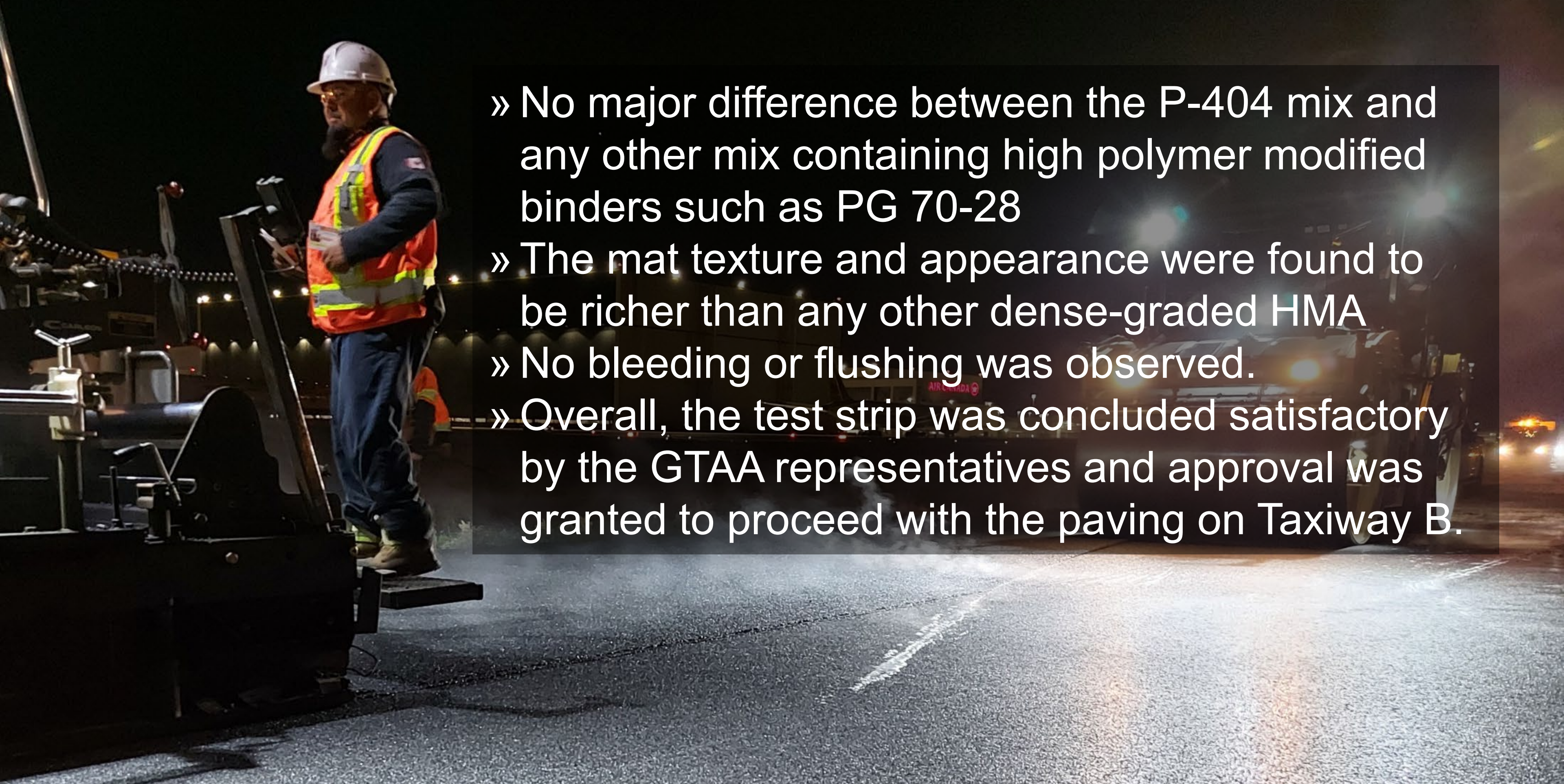
PAVING 50MT TEST STRIP (OCTOBER 13, 2020)

- Thickness varying between 45 to 60 mm
- 97 to 98% of MRD using nuclear density gauge after 4 passes of tandem vibratory steel roller

PAVING 50MT TEST STRIP (OCTOBER 13, 2020)

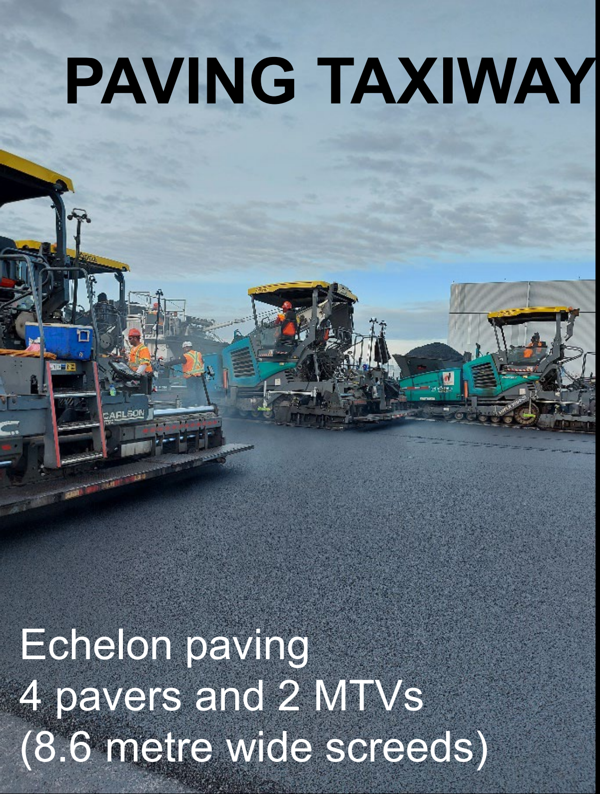
- In-situ density at the joint was recorded 94 to 96% of MRD.
- The joint was relatively colder than compaction temperature when second lane was placed

PAVING 50MT TEST STRIP (OCTOBER 13, 2020)



- No major difference between the P-404 mix and any other mix containing high polymer modified binders such as PG 70-28
- The mat texture and appearance were found to be richer than any other dense-graded HMA
- No bleeding or flushing was observed.
- Overall, the test strip was concluded satisfactory by the GTAA representatives and approval was granted to proceed with the paving on Taxiway B.

PAVING TAXIWAY BRAVO (OCTOBER 14, 2020)



Echelon paving
4 pavers and 2 MTVs
(8.6 metre wide screeds)

Compaction train: Caterpillar steel rollers: CB15, CB34 and CB64.

Roughly 6 roller passes – targeted average in-place density of 97.5% of MRD.

PAVING TAXIWAY ALPHA (JUNE 15, 2021)

- With experience gained through 2020 P-404 trials, 500 tonnes of the P-404 mix was placed on Taxiway A at the GTAA on June 15, 2021.
- Overall, the trial was concluded successful and will be monitored for the long-term field performance.

SUMMARY

- FAA P-404 mix can be designed using locally-sourced aggregate and binder
- Finer mix with 2.5% design air voids - higher in-place density and durability
- Use of Performance testing were found significantly helpful in complementing the volumetric properties – moving toward ***performance-verified specification***
- Production and paving workability found satisfactory – breaking barriers and initial uneasiness toward fine, rich & highly modified binder (i.e. PG 82-28FR)
- Field follow-up has indicated good performance so far. A follow-up CTAA paper is intended to be prepared to report five-year field follow-up on these sections

TAXIWAY ALPHA AND BRAVO - SEPTEMBER 2022

QUESTIONS

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